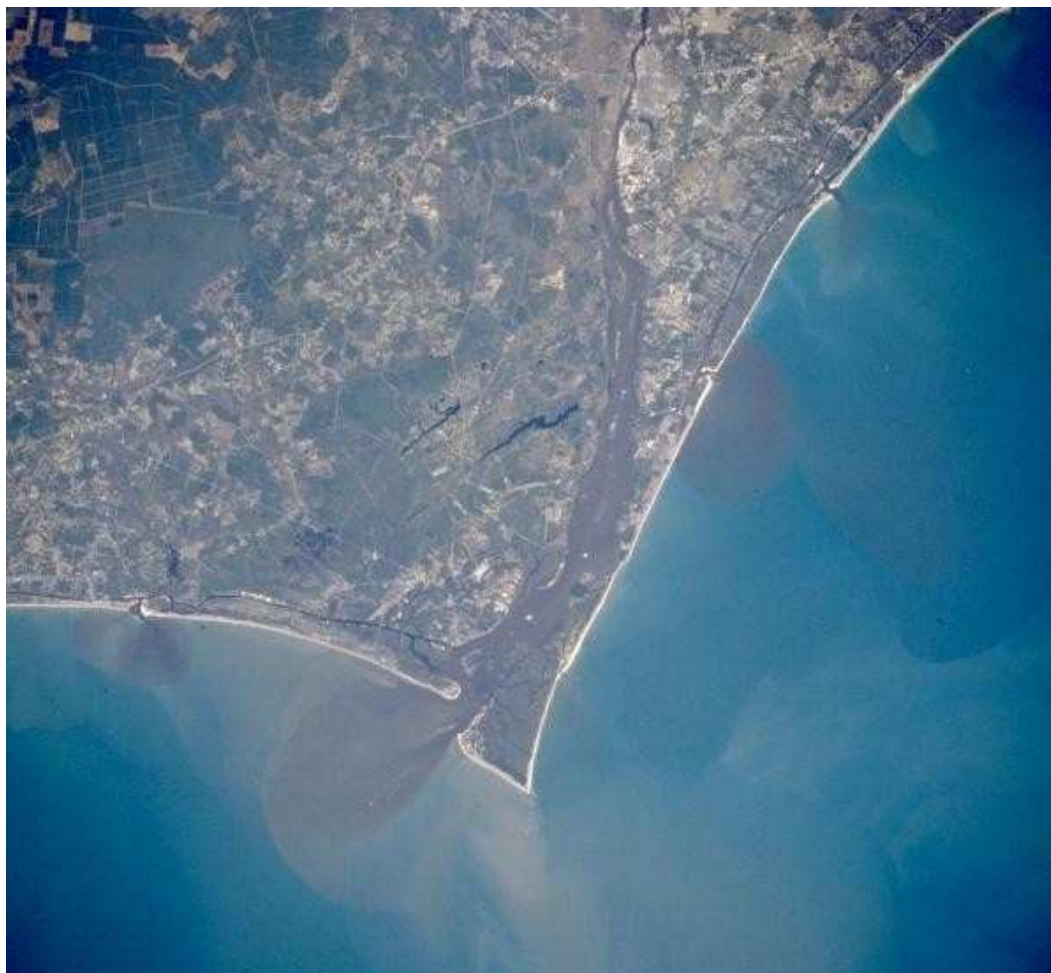


*Environmental Assessment of the Lower
Cape Fear River System, 2003-2004*



By

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Executive Summary

Multiparameter water sampling for the Lower Cape Fear River Program (LCFRP) has been ongoing since June 1995. Scientists from the University of North Carolina Wilmington (UNCW) perform the sampling effort. The LCFRP currently encompasses 35 water sampling stations throughout the Cape Fear, Black, and Northeast Cape Fear River watersheds. The LCFRP sampling program includes physical, chemical, and biological water quality measurements, analyses of the benthic and epibenthic macroinvertebrate communities, and assessment of the fish communities. Principal conclusions of the UNCW researchers conducting these analyses are presented below, with emphasis on the period January 2003-December 2004. The opinions expressed are those of UNCW scientists and do not necessarily reflect viewpoints of individual contributors to the Lower Cape Fear River Program.

The mainstem lower Cape Fear River is characterized by reasonably turbid water containing moderate to high levels of inorganic nutrients. It is fed by two large blackwater rivers (the Black and Northeast Cape Fear Rivers) that have low levels of turbidity, but highly colored water, with less inorganic nutrient content than the mainstem. While nutrients are reasonably high in the river channels, algal blooms are rare because light is attenuated by water color or turbidity, and flushing is high. Periodic algal blooms are seen in the tributary stream stations, some of which are impacted by point source discharges. Below some point sources, nutrient loading can be high and fecal coliform contamination occurs. Other stream stations drain blackwater swamps or agricultural areas, some of which periodically show elevated pollutant loads or effects.

Due to a drought, the summer of 2002 had been characterized by high salinity in the estuary and main river channel. USGS records showed a considerable increase in river discharge in 2003, but in 2004 discharge again decreased. This was reflected in the water quality data, as 2004 had increased salinity but decreased concentrations of a number of nutrient and other water quality concentrations (particularly turbidity) in the main river channel and estuary. In 2003-2004 low dissolved oxygen remained a major problem in the LCFR basin, with a summer sag in the lower river and upper estuary, and some stream stations (ANC, NC403, GS and SR) were impacted severely. Regarding stream stations, chronic or periodic high nutrient levels were found at a number of sites, including ANC, BC117, 6RC, ROC, NC403, PB and SAR. Algal blooms were rare in 2003-2004, primarily occurring at PB, a nutrient-impacted stream site downstream of a point source. Several stream stations, particularly BCRR, BC117, LRC, BRN and HAM showed high fecal coliform counts on a number of occasions. Data from May-December 2004 showed that biochemical oxygen demand (BOD) concentrations in several Northeast Cape Fear River watershed stream stations were considerably higher than BOD concentrations in Black River watershed stream stations. Water column metals concentrations were not problematic during the period 2003-2004.

This report includes an in-depth look at use support ratings for each subbasin, comparing the results of the North Carolina Division of Water Quality's 2000 Basinwide Management Plan with the UNCW-LCFRP's assessments of the 2003-2004 sampling

years. The UNCW-LCFRP utilized definitions for use support that consider a water body to be of poor quality if the water quality standard for a given parameter is in violation > 25% of the time, of fair quality if the standard is in violation between 11 and 25% of the time, and good quality if the standard is violated no more than 10% of the time. UNCW also considers nutrient loading in water quality assessments, based on published experimental and field scientific findings. For the 2003-2004 period UNCW rated all stations as good in terms of chlorophyll *a*, and 83% of the sites were good in terms of turbidity. However, 26% of the stations had either fair or poor water quality in terms of fecal coliform bacterial contamination. Using the 5.0 mg/L standard 63% of the stations were fair to poor in terms of dissolved oxygen concentrations, whereas using the 4.0 mg/L "swamp water" standard 51% of the sites were rated poor or fair. In addition, UNCW considered 26% of the stations to be negatively impacted by excessive nutrient loading.

Researchers at the University of North Carolina Wilmington's Lower Cape Fear River Program performed a pilot study in 2003-2004 to assess metals and organic contaminant concentrations at three areas in the Lower Cape Fear River system. This pilot study was funded by the North Carolina Attorney General's Office as part of the Smithfield Agreement. Sites examined were Livingston Creek along the mainstem of the Cape Fear River near Riegelwood, Six Runs Creek in the Black River Basin, and Rockfish Creek in the Northeast Cape Fear River basin. The results of the investigation showed that levels of metals and organic pollutants in the sediments were below limits considered harmful to aquatic life. However, results of fish tissue and clam tissue analyses showed that concentrations of arsenic, cadmium, mercury, selenium, and now-banned PCBs (polychlorinated biphenyls) and the pesticide Dieldrin were above levels considered safe for human consumption by the U.S. EPA and North Carolina Health Director's Office. The reason the levels are elevated in the fish and clams but not the sediments is that these pollutants become more concentrated as they move up the food chain (from water and sediments to algae and insects to higher organisms), a process called biomagnification. These pollutants will also biomagnify in humans. Because this indicates a direct threat to human health, we recommend that a large-scale study be funded to assess levels of these pollutants in fish and shellfish at stations distributed throughout the lower Cape Fear Watershed.

It is important to recognize that oysters are important for several reasons in the estuarine environment. While traditional efforts to manage oyster populations have focused solely on the value of oysters as a fishery our effort in the last 10 years have been devoted to raising public awareness of the ecosystem services that oysters provide, including filtration of pollutants, erosion control, habitat enhancement, support of other fisheries, and enhanced nutrient cycling. Particularly in the last five years a number of conservation and community groups have initiated restoration for the purpose of enhancing these other functions of oysters. As these types of efforts gain recognition it is critical that we initiate the types of studies described here in order to provide information and recommendations that will increase the likelihood of success for these efforts. It is also important to point out that these efforts can and do help oyster production as well.

The evaluation of North Carolina oyster stocks on a regional basis, with a focus on developing an oyster stock with consistent performance (survivorship and growth) in North Carolina waters, has great potential for both the oyster growers and restoration efforts within the state. High variability in oyster yields between years, and among regions within the state highlights the need for studies that compare the performance of oysters from a variety of local areas within the state. We performed a study that evaluated the potential for stock differentiation among oysters from distinct estuaries by comparing growth and survivorship among oysters collected from four locations within southeastern North Carolina as well as from a hatchery line that is typically available for commercial production. The results showed that stock performance, both growth and survivorship, are strongly influenced by local conditions. While the differences were detectable they did not follow a clear site pattern, though growth tended to be less for White Oak and Cape Fear stocks, and survivorship less for Cape Fear stocks. It is important to realize that while oysters at some sites may demonstrate good survivorship this may not necessarily translate into high growth. Factors enhancing one aspect of performance may not enhance the other.

Because larval supply is the most critical point in enhancing oyster populations in the Cape Fear River and the most difficult to overcome, we measured larval settlement among three sites in the Cape Fear River (Carolina Beach State Park, Fort Fisher, and Southport) and control sites in the New River and Stump Sound. Our results showed that larval settlement in the Cape Fear River is highly variable both temporally and spatially. Oyster populations in the Cape Fear River seem to be limited in part by available settlement substrate. Oysters at the site with the highest density of live oysters showed signs of overcrowding and poor fitness. Thus, substantially increasing the amount of available substrate for larval oyster settlement should prove to be a useful tool for increasing viable oyster populations in the lower Cape Fear River Estuary. Enhancement of oyster populations in the Cape Fear Estuary would have potentially beneficial impacts to water quality, to the future of the oyster fishery and to finfish populations in this region.

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1.0 Introduction

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The Lower Cape Fear River Program is a unique science and education program that has a mission to develop an understanding of processes that control and influence the ecology of the Cape Fear River, and to provide a mechanism for information exchange and public education. This Program provides a forum for dialogue among the various Cape Fear River user groups and encourages interaction among them. Overall policy is set by an Advisory Board consisting of representatives from citizen's groups, local government, industries, academia, the business community, and regulatory agencies. This report represents the scientific conclusions of the UNCW researchers participating in this Program, and does not necessarily reflect opinions of all other Program participants. This report focuses on the period January 2003 through December 2004.

The scientific basis of the Program consists of the implementation of an ongoing comprehensive physical, chemical, and biological monitoring program. Another part of the mission is to develop and maintain a data base on the Cape Fear basin and make use of this data to develop management plans. Presently the Program has amassed a ten-year (1995-2004) data base, freely available to the public. Using this monitoring data as a framework, the Program goals also include focused scientific projects and investigation of pollution episodes. The scientific aspects of the Program are carried out by investigators from the University of North Carolina Wilmington Center for Marine Science. The monitoring program was developed by the Lower Cape Fear River Program Technical Committee, which consists of representatives from UNCW, the North Carolina Division of Water Quality, The NC Division of Marine Fisheries, the US Army Corps of Engineers, technical representatives from streamside industries, the City of Wilmington Wastewater Treatment Plants, Cape Fear Community College, Cape Fear River Watch, the North Carolina Cooperative Extension Service, the US Geological Survey, forestry and agriculture organizations, and others. This integrated and cooperative program was the first of its kind in North Carolina.

Broad-scale monthly water quality sampling at 16 stations in the estuary and lower river system began in June 1995 (directed by Dr. Michael Mallin). Sampling was increased to 34 stations in February of 1996, and 35 stations in February 1998. The Lower Cape Fear River Program added another component concerned with studying the benthic macrofauna of the system in 1996. This component is directed by Dr. Martin Posey of the UNCW Biology Department and includes the benefit of additional data collected by the Benthic Ecology Laboratory under Sea Grant and NSF sponsored projects in the Cape Fear Estuary. The third major biotic component (added in January 1996) was an extensive fisheries program directed by Dr. Mary Moser of the UNCW Center for Marine Science Research, with subsequent (1999) overseeing by Mr. Michael Williams and Dr. Thomas Lankford of UNCW-CMS. This program involved cooperative sampling with the North Carolina Division of Marine Fisheries and the North Carolina Wildlife Resources

Commission. The fisheries program ended in December 1999, but was renewed with additional funds from the Z. Smith Reynolds Foundation from spring – winter 2000, and has been operational periodically for special projects since that period. The regular sampling that was conducted by UNCW biologists was assumed by the North Carolina Division of Marine Fisheries.

1.1. Site Description

The mainstem of the Cape Fear River is formed by the merging of the Haw and the Deep Rivers in Chatham County in the North Carolina Piedmont. However, its drainage basin reaches as far upstream as the Greensboro area (Fig. 1.1). The mainstem of the river has been altered by the construction of several dams and water control structures. In the coastal plain, the river is joined by two major tributaries, the Black and the Northeast Cape Fear Rivers (Fig. 1.1). These blackwater streams drain extensive riverine swamp forests and add organic color to the mainstem. The watershed (about 9,149 square miles) is the most heavily industrialized in North Carolina with 244 permitted wastewater discharges and (as of 2000) over 1.83 million people residing in the basin (NCDENR 2005). Approximately 24% of the land use in the watershed is devoted to agriculture and livestock production (NCDENR 2005), with livestock production dominated by swine and poultry operations. Thus, the watershed receives considerable point and non-point source loading of pollutants.

Water quality is monitored by boat at ten stations in the Cape Fear Estuary (from Navassa to Southport) and one station in the Northeast Cape Fear Estuary (Table 1.1; Fig. 1.1). Riverine stations sampled by boat include NC11, AC, DP, IC, and BBT (Table 1.1; Fig. 1.1). NC11 is located upstream of any major point source discharges in the lower river and estuary system, and is considered to be representative of water quality entering the lower system. BBT is located on the Black River between Thoroughfare and the mainstem Cape Fear, and is influenced by both rivers. We consider B210 and NCF117 to represent water quality entering the lower Black and Northeast Cape Fear Rivers, respectively. Data has also been collected at stream and river stations throughout the Cape Fear, Northeast Cape Fear, and Black River watersheds (Table 1.1; Fig. 1.1). Data collection at a station in the Atlantic Intracoastal Waterway was initiated in February 1998 to obtain water quality information near the Southport Wastewater Treatment Plant discharge.

The LCFRP has a website that contains maps and an extensive amount of past water quality, benthos, and fisheries data gathered by the Program available at:

www.uncwil.edu/cmsr/aquaticcecology/lcfrp/

This report contains five sections assessing LCFRP data. Section 2 presents an overview of physical, chemical, and biological water quality data from the 35 individual stations, and provides tables of raw data as well as figures showing spatial or temporal trends. In Section 3 we analyze our data by sub-basin, compare our results with DWQ's 2000 Basinwide Plan, and make use support assessments for dissolved oxygen, turbidity, chlorophyll *a*, metals, and fecal coliform bacterial abundance. We also utilize

other relevant parameters such as nutrient concentrations to aid in these assessments. This section is designed so that residents of a particular sub-basin can see what the water quality is like in his or her area based on LCFRP data collections.

Section 4 presents the results of a pilot project designed to assess the concentration of priority pollutant metals in sediments, bottom feeding fish, and freshwater clams collected from a limited number of locations in the three main tributaries (the Cape Fear, Black, and Northeast Cape Fear Rivers). In Sections 5 and 6 we present an assessment of the benthic community and the results of a special upstream fish community project in the Lower Cape Fear basin.

1.2. References Cited

NCDENR. 2005. Cape Fear River Basinwide Water Quality Plan (Draft). North Carolina Department of Environment and Natural Resources, Division of Water Quality/Planning, Raleigh, NC, 27699-1617.

Table 1.1. Description of sampling locations in the Cape Fear Watershed, 2003 - 2004, including UNCW designation and NCDWQ station designation number.

UNCW St.	DWQ No.	Location
High order river and estuary stations		
NC11 GPS	B8360000	At NC 11 bridge on Cape Fear River (CFR) N 34.39663 W 78.26785
LVC GPS	B8445000	40 m up Livingston Creek from Cape Fear River N 34.35180 W 78.20128
AC GPS	B8450000	5 km downstream from International Paper on CFR N 34.35547 W 78.17942
DP GPS	B8460000	At Dupont Intake above Black River N 34.33595 W 78.05337
IC GPS	B9030000	Cluster of dischargers upstream of Indian Cr. on CFR N 34.30207 W 78.01372
B210 GPS	B9000000	Black River at Highway 210 bridge N 34.43138 W 78.14462
BBT GPS	none	Black River between Thoroughfare and Cape Fear River N 34.35092 W 78.04857
NCF117 GPS	B9580000	Northeast Cape Fear River at Highway 117, Castle Hayne N 34.36342 W 77.89678
NCF6 GPS	B9670000	Northeast Cape Fear River near GE dock N 34.31710 W 77.95383
NAV GPS	B9050000	Railroad bridge over Cape Fear River at Navassa N 34.25943 W 77.98767
HB GPS	B9050100	Cape Fear River at Horseshoe Bend N 34.24372 W 77.96980
BRR GPS	B9790000	Brunswick River near new boat ramp in Belville N 34.22138 W 77.97868

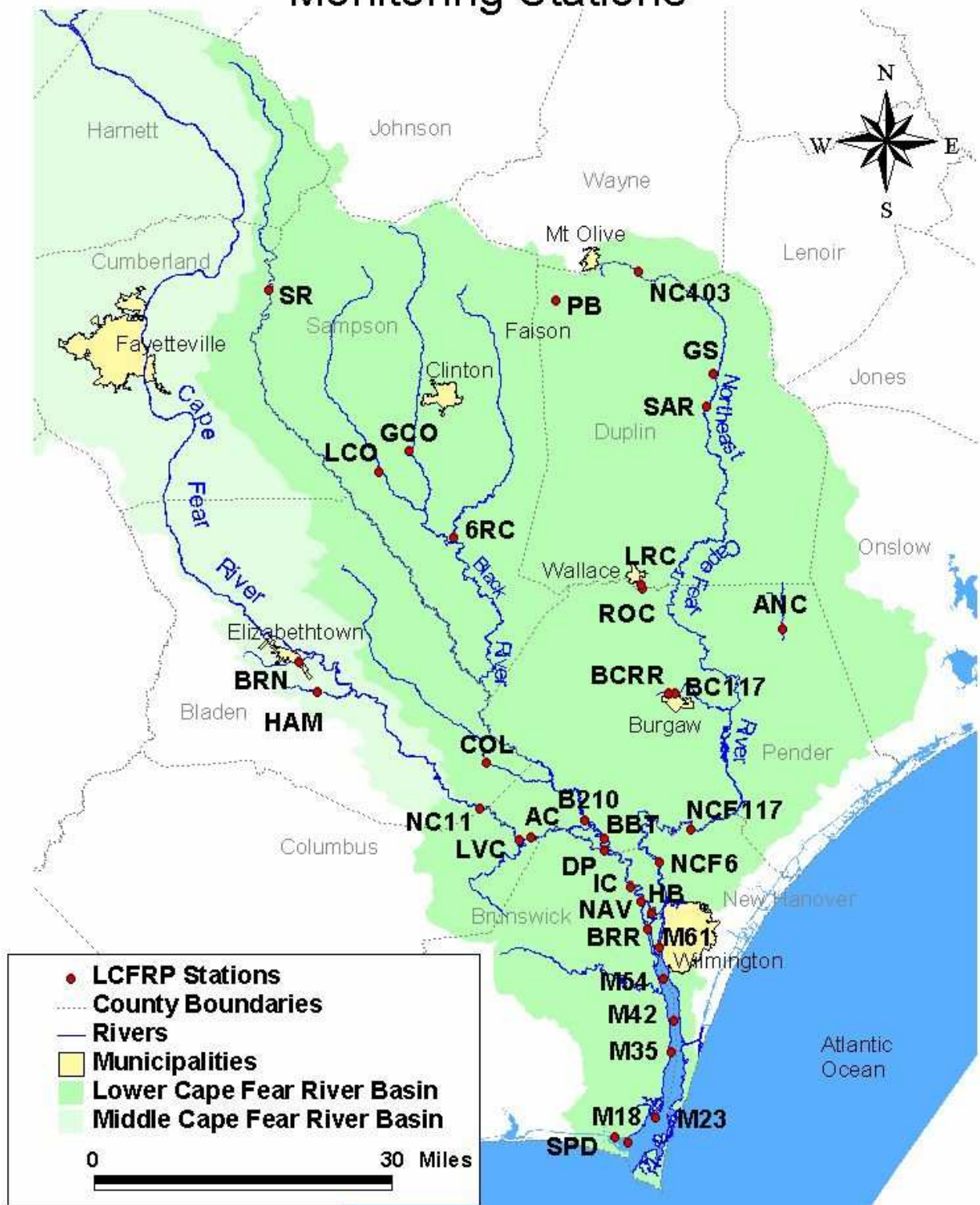
M61 GPS	B9750000	Channel Marker 61, downtown at N.C. State Port N 34.19377 W 77.95725
M54 GPS	B7950000	Channel Marker 54, 5 km downstream of Wilmington N 34.13933 W 77.94595
M42 GPS	B9845100	Channel Marker 42 near Keg Island N 34.09017 W 77.93355
M35 GPS	B9850100	Channel Marker 35 near Olde Brunswick Towne N 34.03408 W 77.93943
M23 GPS	B9910000	Channel Marker 23 near CP&L intake canal N 33.94560 W 77.96958
M18 GPS	B9921000	Channel Marker 18 near Southport N 33.91297 W 78.01697
SPD GPS	B9980000	1000 ft W of Southport WWT plant discharge on ICW N 33.91708 W 78.03717

Tributary stations collected from land

SR GPS	B8470000	South River at US 13, below Dunn runoff N 35.15600 W 78.64013
GCO GPS	B8604000	Great Coharie Creek at SR 1214 N 34.91857 W 78.38873
LCO GPS	B8610001	Little Coharie Creek at SR 1207 N 34.83473 W 78.37087
6RC GPS	B8740000	Six Runs Creek at SR 1003 (Lisbon Rd.) N 34.79357 W 78.31192
BRN GPS	B8340050	Browns Creek at NC 87 N 34.61360 W 78.58462
HAM GPS	B8340200	Hammonds Creek at SR 1704 N 34.56853 W 78.55147
COL GPS	B8981000	Colly Creek at NC 53 N 34.46500 W 78.26553

ANC GPS	B9490000	Angola Creek at NC 53 N 34.65705 W 77.73485
NC403 GPS	B9090000	Northeast Cape Fear below Mt. Olive Pickle at NC403 N 35.17838 W 77.98028
PB GPS	B9130000	Panther Branch below Cates Pickle N 35.13445 W 78.13630
GS GPS	B9191000	Goshen Swamp at NC 11 N 35.02923 W 77.85143
SAR GPS	B9191500	Northeast Cape Fear River near Sarecta N 34.97970 W 77.86251
LRC GPS	B9460000	Little Rockfish Creek at NC 11 N 34.72247 W 77.98145
ROC GPS	B9430000	Rockfish Creek at US 117 N 34.71689 W 77.97961
BCRR GPS	B9500000	Burgaw Canal at Wright St., above WWTP N 34.56334 W 77.93481
BC117 GPS	B9520000	Burgaw Canal at US 117, below WWTP N 34.56391 W 77.92210

Lower Cape Fear River Program Monitoring Stations



2.0 - Physical, Chemical, and Biological Characteristics of the Lower Cape Fear River and Estuary

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2.1 - Introduction

This section of the report includes a discussion of the physical, chemical, and biological water quality parameters, concentrating on the January 2003-December 2004 Lower Cape Fear River Program monitoring period. These parameters are interdependent and define the overall condition of the river. Physical parameters measured during this study included water temperature, dissolved oxygen, turbidity, salinity, conductivity and pH. The chemical makeup of the Cape Fear River was investigated by measuring the magnitude and composition of nitrogen and phosphorus in the water, as well as concentrations of United States Environmental Protection Agency (US EPA) priority pollutant metals. Three biological parameters including fecal coliform bacteria, chlorophyll *a* and biochemical oxygen demand were examined.

2.2 - Materials and Methods

All samples and field parameters collected for the estuarine stations of the Cape Fear River (NAV down through M18) were gathered on an ebb tide. This was done so that the data better represented the river water flowing downstream through the system rather than the tidal influx of coastal ocean water. Sample collection and analyses were conducted according to the procedures in the Lower Cape Fear River Program Quality Assurance/Quality Control (QA/QC) manual, which has been approved by the NC Division of Water Quality.

Physical Parameters

Water Temperature, pH, Dissolved Oxygen, Turbidity, Salinity, Conductivity

Field parameters were measured at each site using a YSI 6920 (or 6820) multi-parameter water quality sonde displayed on a YSI 610D (or 650 MDS). Each parameter is measured with individual probes on the sonde. At stations sampled by boat (see Table 1.1) physical parameters were measured at 0.1 m, the middle of the water column, and at the bottom (up to 12 m). Occasionally, high flow prohibited the sonde from reaching the actual bottom and measurements were taken as deep as possible. At the terrestrially sampled stations the physical parameters were measured at a depth of 0.1 m.

Chemical Parameters

Nutrients

All nutrient analyses were performed at the UNCW Center for Marine Science (CMS) for samples collected prior to January 1996. A local state-certified analytical laboratory was contracted to conduct all subsequent analyses except for orthophosphate, which is performed at CMS. The following methods detail the techniques used by CMS personnel for orthophosphate analysis.

Orthophosphate (PO_4^{-3})

Water samples were collected ca. 0.2 m below the surface in triplicate in amber 125 mL Nalgene plastic bottles and placed on ice. In the laboratory 50 mL of each triplicate was filtered through separate 1.0 micron pre-combusted glass fiber filters, which were frozen and later analyzed for chlorophyll *a*. The triplicate filtrates were pooled in a glass flask, mixed thoroughly, and approximately 100 mL was poured into a 125 mL plastic bottle to be analyzed for orthophosphate. Samples were frozen until analysis.

Orthophosphate analyses were performed in duplicate using an approved US EPA method for the Technicon AutoAnalyzer (Method 365.5). In this technique the orthophosphate in each sample reacts with ammonium molybdate and antimony potassium tartrate in an acidic medium (sulfuric acid) to form an antimony-phospho-molybdate complex. The complex is then reacted with ascorbic acid and forms a deep blue color. The intensity of the color is measured at a wavelength of 880 nm by a colorimeter and displayed on a chart recorder. Standards and spiked samples were analyzed for quality assurance.

Biological Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria were analyzed at a state-certified laboratory contracted by LCFRP. Samples were collected approximately 0.2 m below the surface in sterile plastic bottles provided by the contract laboratory and placed on ice for no more than six hours before analysis.

*Chlorophyll *a**

The analytical method used to measure chlorophyll *a* is described in Welschmeyer (1994) and US EPA (1997) and was performed by CMS personnel. Chlorophyll *a* concentrations were determined directly from the 1.0 micron filters used for filtering samples for orthophosphate analysis. All filters were wrapped individually in foil, placed in airtight containers and stored in the freezer. During analysis each filter is immersed in 10 mL of 90% acetone for 24 hours, which extracts the chlorophyll *a* into solution. Chlorophyll *a* concentration of each solution is measured on a Turner 10-AU fluorometer. The

fluorometer uses an optimal combination of excitation and emission bandwidth filters which reduces the errors inherent in the acidification technique.

Biochemical Oxygen Demand (BOD)

Five sites were originally chosen for BOD analysis. One site was located at NC11, upstream of International Paper, and a second site was at AC, about 3 miles downstream of International Paper (Fig.1.1). Two sites were located in blackwater rivers (NCF117 and B210) and one site (BBT) was situated in an area influenced by both the mainstem Cape Fear River and the Black River. For the sampling period May 2000-April 2004 additional BOD data were collected at stream stations 6RC, LCO, GCO, BRN, HAM and COL. In May 2004 those stations were dropped and sampling commenced at ANC, SAR, GS, N403, ROC and BC117. The procedure used for BOD analysis was Method 5210 in Standard Methods (APHA 1995). Samples were analyzed for both 5-day and 20-day BOD. During the analytical period, samples were kept in airtight bottles and placed in an incubator at 20° C. All experiments were initiated within 5 hours of sample collection. Samples were analyzed in duplicate. Dissolved oxygen measurements were made using a YSI Model 57 meter that was air-calibrated. No adjustments were made for pH since most samples exhibited pH values within or very close to the desired 6.5-7.5 range. Several sites have naturally low pH and there was no adjustment for these samples because it would alter the natural water chemistry and affect true BOD.

2.3 - Results and Discussion

This section includes results from monitoring of the physical, biological, and chemical parameters at all stations for the time period January 2003-June 2004. Discussion of the data focuses mainly on the river channel stations, but poor water quality conditions at stream stations will also be discussed. The contributions of the two large blackwater tributaries, the Northeast Cape Fear River and the Black River, are represented by conditions at NCF117 and B210, respectively. The Cape Fear Region did not experience any significant hurricane activity during this monitoring period (after major hurricanes in 1996, 1998, and 1999). Therefore this report reflects mixed flow conditions for the Cape Fear River and Estuary.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 3.3 to 30.5 °C and individual station annual averages ranged from 15.9 to 19.9 °C (Tables 2.1 and 2.2). Highest temperatures occurred during July of both years and lowest temperatures during February 2004. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters.

Salinity

Salinity at the estuarine stations ranged from 0.0 to 35.1 practical salinity units (psu) and station annual means ranged from 0.3 to 26.0 psu (Tables 2.3 and 2.4). Lowest salinities occurred in July 2003 and highest salinities occurred in April and November 2004. Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities. Annual mean salinity for 2004 was slightly higher than the nine-year average for 1996-2004 at all stations, except for M35-SPD (Figure 2.1). Relative to the previous three years 2003 had high river discharge, but river discharge in 2004 subsequently decreased again (see USGS data at <http://nc.water.usgs.gov>). This influenced salinity, and also appeared to lead to a reduction in concentration of certain nutrients and other parameters (TSS, turbidity, light attenuation) in the main channel and estuary stations (see below).

Conductivity

Conductivity at estuarine stations ranged from 0.1 to 49.8 mS/cm and from 0.1 to 5.7 mS/cm at the freshwater stations (Tables 2.5-2.6). Temporal conductivity patterns followed those of salinity. Dissolved ionic compounds increase the conductance of water, therefore, conductance increases and decreases with salinity, often reflecting river flow conditions due to rainfall. Conductivity may also reveal point source pollution sources, as is seen at BC117, which is below a municipal wastewater discharge.

pH

pH values ranged from 3.3 to 10.3 and stations annual medians ranged from 3.7 to 7.9 (Tables 2.7-2.8). pH was typically lowest upstream due to acidic swamp water inputs and highest downstream as alkaline seawater mixes with the river water. Some unusually high pH values at BC117 and ANC are most likely due to industrial discharges and or algal blooms or macrophyte (see also very high dissolved oxygen concentrations). Low pH values at COL predominate because of naturally acidic blackwater inputs.

Dissolved Oxygen

Dissolved oxygen (DO) problems are a major water quality concern in the Cape Fear River and its estuary, and several of the tributary streams (Mallin et al. 1999; 2000; 2001a; 2001b; 2002a; 2002b; 2003; 2004). Concentrations in 2003-2004 ranged from 0.2 to 14.4 mg/L and station annual means ranged from 3.8 to 9.5 mg/L (Tables 2.9-2.10). Average annual DO levels at the river channel stations for 2004 were very close to the average for 1996-2004 (Figure 2.2). Dissolved oxygen levels were lowest during the summer (Tables 2.9-2.10), often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. Working synergistically to lower oxygen levels are two factors: lower oxygen carrying capacity in warmer water and increased bacterial respiration (or biochemical oxygen demand, BOD), due to higher temperatures in summer. These hypoxic conditions could have negative impacts on the biota in the Cape Fear River.

There is a dissolved oxygen sag in the main river channel that begins at DP below a paper mill discharge and persists into the mesohaline portion of the estuary (Fig. 2.2). Mean oxygen levels were highest at the upper river stations NC11 and AC and in the middle to lower estuary at station M23. Lowest mainstem mean DO levels occurred in 2004 at the lower river and upper estuary stations IC (7.3 mg/L) and M61 (7.2 mg/L). Discharge of high BOD waste from the paper/pulp mill just above the AC station (Mallin et al. 2003), as well as inflow of blackwater from the Northeast Cape Fear and Black Rivers, helps to diminish oxygen in the upper estuary. As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2004 mean = 6.2, B210 2004 mean = 6.9). These rivers are classified as blackwater systems because of their tea colored water. As the water passes through swamps en route to the river channel, tannins from decaying vegetation leach into the water, resulting in the observed color. Decaying vegetation on the swamp floor has an elevated biochemical oxygen demand and usurps oxygen from the water, leading to naturally low dissolved oxygen levels. Runoff from concentrated animal feeding operations (CAFOs) may also contribute to chronic low dissolved oxygen levels in these blackwater rivers (Mallin et al. 1998; 1999; Mallin 2000). The Northeast Cape Fear River in general seems to be more oxygen stressed than the Black River; from 2003-2004 NCF117 had DO concentrations below 4.0 mg/L 33% of the time sampled, while during that same period B210 had DO below 4.0 mg/L 13% of the occasions sampled (Tables 2.9-2.10)

Several stream stations were severely stressed in terms of low dissolved oxygen during the year January 2003-December 2004. ANC had DO levels below 4.0 mg/L 46% of the occasions sampled, NC403 50%, GS 42%, BCRR 25% and SR 50% (Tables 2.9-2.10). Some of this can be attributed to low water conditions and some potentially to CAFO runoff; however point-source discharges also likely contribute to low dissolved oxygen levels at NC403 and possibly SR, especially via nutrient loading (Mallin et al. 2001a; 2002a; 2004).

Field Turbidity

Turbidity levels ranged from 0 to 140 nephelometric turbidity units (NTU) and station annual means ranged from 1 to 32 NTU (Tables 2.11-2.12). Annual mean turbidity levels for 2003 were higher than those for 2004. Highest 2003 and 2004 mean turbidities were at the upper river sites N11, AC and DP (all 32 NTU) with turbidities gradually decreases downstream through the estuary (Figure 2.3). Turbidity was lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river.

Note: The LCFRP uses nephelometers designed for field use, which allows us to acquire in situ turbidity from a natural situation. North Carolina regulatory agencies are required to use turbidity values from water samples removed from the natural system, put on ice until arrival at a State-certified laboratory, and analyzed using laboratory nephelometers. Standard Methods notes that transport of samples and temperature change alters true

turbidity readings. Our analysis of samples using both methods shows that lab turbidity is nearly always substantially lower than field turbidity.

Total Suspended Solids

Total suspended solid (TSS) values system wide ranged from 0 to 109 mg/L with station annual means from 0.8 to 21.3 mg/L (Tables 2.13-2.14). For the river channel stations TSS was highest from the upper river and decreasing through the estuary. Although total suspended solids (TSS) and turbidity both quantify suspended material in the water column, they do not always go hand in hand. High TSS does not mean high turbidity and vice versa. This anomaly may be explained by the fact that fine clay particles are effective at dispersing light and causing high turbidity readings, while not resulting in high TSS. On the other hand, large organic or inorganic particles may be less effective at dispersing light, yet their greater mass results in high TSS levels.

Light Attenuation

The attenuation of solar irradiance through a water column is measured by a logarithmic function (k) per meter. The higher this light attenuation coefficient is, the more strongly light is attenuated (through absorbance or reflection) in the water column. River and estuary light attenuation coefficients ranged from 1.08 to 6.20/m and station annual means ranged from 1.45 at M18 in 2004 to 4.51 /m at NCF6 in 2003 (Tables 2.15-2.16). Annual light attenuation means for this monitoring period were slightly lower than for the nine-year period 1996-2004 (Figure 2.4).

High light attenuation did not always coincide with high turbidity. Blackwater, though low in turbidity, will attenuate light through absorption of solar irradiance. At NCF6 and BBT, blackwater stations with moderate turbidity levels, light attenuation was high. Compared to other North Carolina estuaries the Cape Fear has high average light attenuation. The high average light attenuation is a major reason why phytoplankton production in the major rivers and the estuary of the LCFR is generally low. Whether caused by turbidity or water color this attenuation tends to limit light availability to the phytoplankton (Mallin et al. 1997; 1999).

Chemical Parameters – Nutrients

Total Nitrogen

Total nitrogen (TN) ranged from 90 to 23,000 $\mu\text{g/L}$ and station annual means ranged from 500 to 7,762 $\mu\text{g/L}$ (Tables 2.17-2.18). Mean total nitrogen was slightly lower in 2004 than for the nine-year mean at all main channel stations (Figure 2.5). Previous research (Mallin et al. 1999) has shown a positive correlation between river flow and TN in the Cape Fear system. Total nitrogen concentrations remained fairly constant down the river and declined from mid-estuary into the lower estuary, most likely reflecting uptake of nitrogen

into the food chain through algal productivity and subsequent grazing by planktivores as well as through dilution and marsh denitrification. The pulp mill above AC is a source of TN, increasing levels at this station slightly over levels at NC11. The blackwater rivers maintained TN concentrations somewhat lower than those found in the mainstem Cape Fear River. One stream station, BC117, had a very high mean of 7,762 µg/L, likely from the upstream Town of Burgaw wastewater discharge. ANC, PB, ROC and SAR (in 2004) had comparatively high TN values among the stream stations. Temporal patterns for TN were not evident.

Nitrate+Nitrite

Nitrate+nitrite (henceforth referred to as nitrate) is the main species of inorganic nitrogen in the Lower Cape Fear River. Concentrations system wide ranged from 5 (detection limit) to 21,300 µg/L and station annual means ranged from 5 to 6,699 µg/L (Table 2.19-2.20). Station annual means for the 2004 monitoring period were slightly lower than the nine-year means (Figure 2.6). The highest riverine nitrate levels were at NC11 (2004 mean = 557 µg/L) indicating that much of this nutrient is imported from upstream. Moving downstream from NC11, nitrate levels decrease most likely as a result of uptake by primary producers, microbial denitrification in riparian marshes and tidal dilution. The blackwater rivers carried low loads of nitrate compared to the mainstem Cape Fear stations, though the Northeast Cape Fear River (NCF117 mean = 242 µg/L) had higher nitrate than the Black River (B210 = 164 µg/L) in 2003. No clear temporal pattern was observable for nitrate.

Several stream stations showed high levels of nitrate on occasion including SAR, NC403, PB, ROC, BC117 and GCO. NC403 and PB are downstream of industrial wastewater discharges and ROC and GCO primarily receive non-point agricultural or animal waste drainage. BC117, with high nitrate levels, exceeded the North Carolina State drinking water standard of 10 mg/L on three occasions. The Town of Burgaw wastewater plant, upstream of BC117, has no nitrate discharge limits. Over the past several years a considerable number of experiments have been carried out by UNCW researchers to assess the effects of nutrient additions to water collected from blackwater streams and rivers (i.e. the Black and Northeast Cape Fear Rivers, and Colly and Great Coharie Creeks). These experiments have collectively found that additions of nitrogen (as either nitrate, ammonium, or urea) significantly stimulate phytoplankton production and BOD increases. Critical levels of these nutrients were in the range of 0.2 to 0.5 mg/L as N (Mallin et al. 1998; Mallin et al. 2001a; Mallin et al. 2002a, Mallin et al. 2004). Thus, we conservatively consider nitrate concentrations exceeding 0.5 mg/L as N in Cape Fear watershed streams to be potentially problematic to the streams environmental health. Blackwater streams where we periodically see concentrations of this magnitude include 6RC, ROC, SAR, BC117, NC403, and PB.

Ammonium

Ammonium concentrations ranged from 10 (detection limit) to 1,180 µg/L and station annual means ranged from 18 to 198 µg/L (Tables 2.21-2.22). The 2004 monitoring period mean ammonium levels were generally lower than the nine-year means at the channel

stations (Figure 2.6). River areas with the highest mean ammonium levels this monitoring period included AC, which is below a pulp mill discharge, and M61, M54 and M42 in the middle estuary. Ocean dilution accounts for decreasing levels down into the estuary. At the stream stations, areas with high levels of ammonium include LVC, ANC, BC117 and PB.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total concentration of organic nitrogen plus ammonium. TKN ranged from 50 to 3,510 $\mu\text{g/L}$ and station annual means ranged from 418 to 1,569 $\mu\text{g/L}$ (Tables 2.23-2.24). Mean TKN for 2004 was similar to or slightly lower than the nine-year mean at the channel stations (Figure 2.8). TKN concentration drops down through the estuary, likely due to ocean dilution and food chain uptake of nitrogen. Measured TKN levels in the blackwater rivers are usually higher than in the mainstem Cape Fear River as a result of the high concentration of organic materials dissolved in the water (Figure 2.8). The stream stations typically have higher TKN as a result of the influence of swamp water with high organic and ammonium content. There were somewhat higher TKN levels during summer months.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from 10 (detection limit) to 3,700 $\mu\text{g/L}$ and station annual means ranged from 25 to 1,273 $\mu\text{g/L}$ (Tables 2.25-2.26). Mean TP for 2004 was lower than the nine-year mean at all channel stations (Figure 2.9). In the river TP is highest at the upper riverine channel stations and declines downstream into the estuary. Some of this decline is attributable to the settling of phosphorus-bearing turbidity, yet incorporation of phosphorus into the food chain is also responsible. A temporal pattern of higher summer TP is a result of increasing orthophosphate, as the spatial pattern of TP is similar to that of orthophosphate.

The experiments discussed above in the nitrate subsection also involved additions of phosphorus, either as inorganic orthophosphate or a combination of inorganic plus organic P. The experiments showed that additions of P exceeding 0.5 mg/L led to significant increases in bacterial counts, as well as significant increases in BOD over control. Thus, we consider concentrations of phosphorus above 0.5 to be potentially problematic to blackwater streams. Streams periodically exceeding this critical concentration included NC403 and BC117, and ROC in 2004 also showed some elevated TP concentrations. Some of these stations (BC117, NC403) are downstream of industrial or wastewater discharges, while ROC is in a non-point agricultural area.

Orthophosphate

Orthophosphate ranged from 0 to 3,700 $\mu\text{g/L}$ and station annual means ranged from 9 to 1,236 $\mu\text{g/L}$ (Tables 2.27-2.28). The 2004 annual means at the channel stations were similar to or lower than the nine-year means (Figure 2.10).

Much of the orthophosphate load is imported into the Lower Cape Fear system from upstream areas, as NC11 typically has the highest levels. The Northeast Cape Fear River had higher orthophosphate levels than the Black River. Orthophosphate can bind to suspended materials and is transported downstream via turbidity; thus high levels of turbidity at the uppermost river stations may be an important factor in the high orthophosphate levels. Turbidity declines toward the estuary because of settling, and orthophosphate concentration also declines. In the estuary, primary productivity helps reduce orthophosphate concentrations by assimilation into biomass. Orthophosphate levels typically reach maximum concentrations during summertime, when anoxic sediment releases bound phosphorus. Also, in the Cape Fear Estuary, summer algal productivity is limited by nitrogen, thereby allowing the accumulation of orthophosphate (Mallin et al. 1997; 1999). In spring, productivity in the estuary is usually limited by phosphorus (Mallin et al. 1997; 1999).

The stream station BC117 had very high orthophosphate levels while ROC, ANC and NC403 had moderately high levels. NC403 and BC117 are strongly influenced by industrial and municipal wastewater discharges, and ANC and ROC by agriculture/animal waste runoff.

Chemical Parameters - EPA Priority Pollutant Metals

Aluminum levels in the Lower Cape Fear system were generally higher in the upper river and decreased toward the lower estuary (Table 2.29). Stream stations were generally low except COL, which is considered pristine swamp water. There is no North Carolina aquatic standard for aluminum.

Arsenic, cadmium, and chromium all maintained concentrations below detection limits at all stations (except As had measurable levels at M23 and M18 in the lower estuary) throughout the year (Tables 2.30, 2.31, and 2.32). The As concentrations were all below the N.C. standard.

Copper concentrations frequently exceeded the state tidal saltwater standard of 3 µg/L at estuarine stations M54, M35, M23 and M18 (Table 2.33). The freshwater standard of 7 µg/L was exceeded four out of nine times at BC117, but did not exceed freshwater standard at the other stream stations sampled.

The LCFRP is an iron-rich system (Table 2.34). All of the freshwater stations except for NCF117, BC117, and SAR maintained average iron concentrations near or above the state standard of 1000 µg/L. Iron concentrations generally decreased down-estuary.

Water-column concentrations of lead, mercury, and nickel were below the analytical detection limit except for nickel, which remained below the N.C. state standard (Table 2.35, 2.36, 2.37). The Ni standard for tidal saltwater was exceeded on several occasions at M54, M35, M23 and M18 (Table 2.37).

Zinc concentrations remained below the state standard at all stations except August 2004, when a concentration of 88 µg/L was recorded from NAV (Table 2.38).

Biological Parameters

Chlorophyll a

During this monitoring period chlorophyll a was generally low at the river and estuarine stations (Tables 2.39-2.40). Chlorophyll a ranged from 0.1 to 102.7 µg/L and station annual means ranged from 0.4 to 17.9 µg/L. Production of chlorophyll a biomass is low to moderate in this system primarily because of light limitation by turbidity in the mainstem and high organic color and low inorganic nutrients in the blackwater rivers. Spatially, highest values are normally found in the mid-to-lower estuary stations because light becomes more available downstream of the estuarine turbidity maximum (Figure 2.11). Chlorophyll a production is extremely limited in the large blackwater tributaries. Highest chlorophyll a concentrations were found during spring and summer.

Substantial phytoplankton blooms occasionally occur at the stream stations (Table 2.40). These streams are generally shallow, so mixing does not carry phytoplankton cells down below the critical depth where respiration exceeds photosynthesis. Thus, when flow conditions permit, elevated nutrient conditions (such as are periodically found in these stream stations) can lead to algal blooms. In areas where the forest canopy opens up large blooms can occur. When blooms occur in blackwater stream stations, they can become sources of BOD upon death and decay, reducing further the low summer dissolved oxygen conditions common to these waters (Mallin et al. 2001; 2002; 2004). Particularly large stream algal blooms occurred in 2004 at PB, which is downstream of a point source discharge.

Biochemical Oxygen Demand

For the main stem river, mean annual five-day biochemical oxygen demand (BOD₅) concentrations were highest at AC, on average about 18% higher than at NC11 suggesting influence from the pulp/paper mill inputs (Table 2.41-2.42). BOD was somewhat lower during the winter.

From 2000 until April 2004 we performed a project aimed at assessing rural Black River system stream contributions to BOD. Results of BOD in several stream stations can be seen in Table 2.41 and 2.42. HAM showed the highest BOD₅ and BOD₂₀ levels, with very little difference among the other stream stations. In May 2004 we changed the stream sampling to the Northeast Cape Fear River watershed. The preliminary data (Table 2.42) shows generally greater BOD concentrations at the Northeast Cape Fear Watershed streams than the Black River Watershed streams. ANC, GS, N403 and ROC all showed large (> 3.5 mg/L) individual BOD₅ measurements during 2004. Station N403 is below a point source, but the other three sites are non-point runoff areas.

Fecal Coliform Bacteria

Fecal coliform (FC) bacterial counts ranged from 0 to 4,360 CFU/100 mL and station annual geometric means ranged from 1 to 169 CFU/100 mL (Tables 2.43-2.44). No clear temporal pattern was evident. The state human contact standard (200 CFU) was exceeded only rarely at the channel stations. FC counts in 2004 were lower at the Cape Fear River stations but similar to or higher at the estuary stations and the blackwater stations compared with the nine-year average (Figure 2.12). FC bacteria show a notable spatial trend of highest counts in the upper estuary-lower river area including stations DP, IC, NAV, HB, BRR, M61 and M54.

Most stream stations surpassed the state standard for human contact of 200 CFU/100 mL on at least one occasion, and several were particularly problematic. Over the two year period BC117 exceeded the state standard 50% of the time, BCRR 38%, PB 29%, HAM 29%, GS, LRC, 6RC and BRN all exceeded the standard 17% of the time. LRC, BC117 and PB are located below point source discharges and the other sites are primarily influenced by non-point source pollution.

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3.0 Use Support by Subbasin in the Lower Cape Fear River System

by

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3.0 Use Support Comparison by Subbasins

This section details comparisons, by subbasin, of the use support ratings determined for dissolved oxygen, turbidity, chlorophyll *a*, fecal coliform bacteria and some nutrient species at the LCFRP sampling sites. Twenty four months of LCFRP data from 2003-2004 is used in the comparisons.

3.1 Introduction

The NC Division of Water Quality prepares a basinwide water quality plan for each of the seventeen major river basins in the state every five years (NCDENR, DWQ Cape Fear River Basinwide Water Quality Plan, July 2000). The basinwide approach is a nonregulatory watershed-based approach to restoring and protecting the quality of North Carolina's surface waters. The first basinwide plan for the Cape Fear River was completed in 1996 and the 2000 report is the first of the five-year interval updates. The goals of the basinwide program are to:

- identify water quality problems and restore full use to impaired waters;
- identify and protect high value resource waters;
- protect unimpaired waters while allowing for reasonable economic growth;
- develop appropriate management strategies to protect and restore water quality;
- assure equitable distribution of waste assimilative capacity for dischargers; and
- improve public awareness and involvement in the management of the state's surface waters.

The US Geological Survey (USGS) identifies 6 major hydrological areas in the Cape Fear River Basin. Each of these hydrologic areas is further divided into subbasins by DWQ. There are 24 subbasins within the Cape Fear River basin, each denoted by 6-digit numbers, 03-06-01 to 03-06-24 (NCDENR, DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

The Division of Water Quality (DWQ) conducts an assessment and determines water classification according to their best-intended uses. Use support ratings are established such as fully supporting (FS) if the standard is exceeded in < 10% of measurements, partially supporting (PS) if the standard is exceeded in 11-25% of measurements, or non supporting (NS) if the standard is exceeded in > 25% of measurements. DWQ also utilizes other criteria, such as the benthic community

composition and fisheries populations (NCDENR, DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

UNCW Aquatic Ecology Laboratory (AEL) researchers have adopted a rating system that incorporates some of the guidelines used by DWQ. We determine use support ratings for the parameters that have a NC State standard including dissolved oxygen, chlorophyll *a*, fecal coliform bacteria, and turbidity as well as nutrient species with levels noted to be problematic in the scientific literature. Our rating system is good quality (G) if standard is exceeded in < 10% of measurements, fair quality (F) if standard is exceeded in 11-25% of measurements, or poor quality (P) if standard is exceeded in > 25% of measurements.

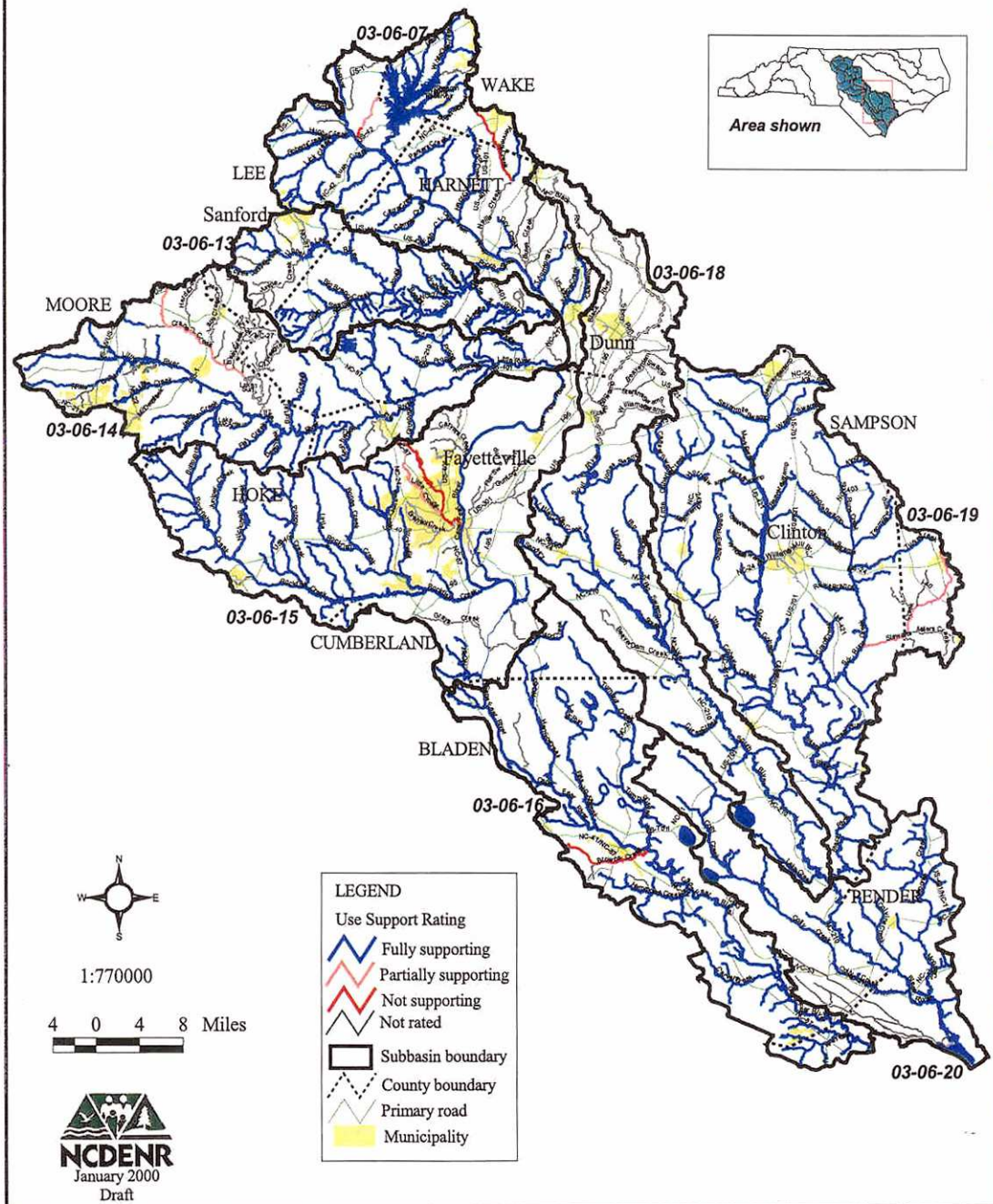
The 35 stations monitored by the LCFRP fall into the middle and lower basins designated by the NC DWQ. The stations are in the following subbasins:

<u>Subbasin #</u>	<u>Basin</u>	<u>LCFRP Stations</u>
03-06-16	middle	BRN, HAM, NC11
03-06-17	lower	LVC, AC, DP, IC, NAV, HB, BRR, M61, M54, M42, M35, M23, M18, SPD
03-06-18	middle	SR
03-06-19	middle	6RC, LCO, GCO
03-06-20	middle	COL, B210, BBT
03-06-21	lower	N403
03-06-22	lower	SAR, GS, PB, LRC, ROC
03-06-23	lower	ANC, BC117, BCRR, NCF6, NCF117

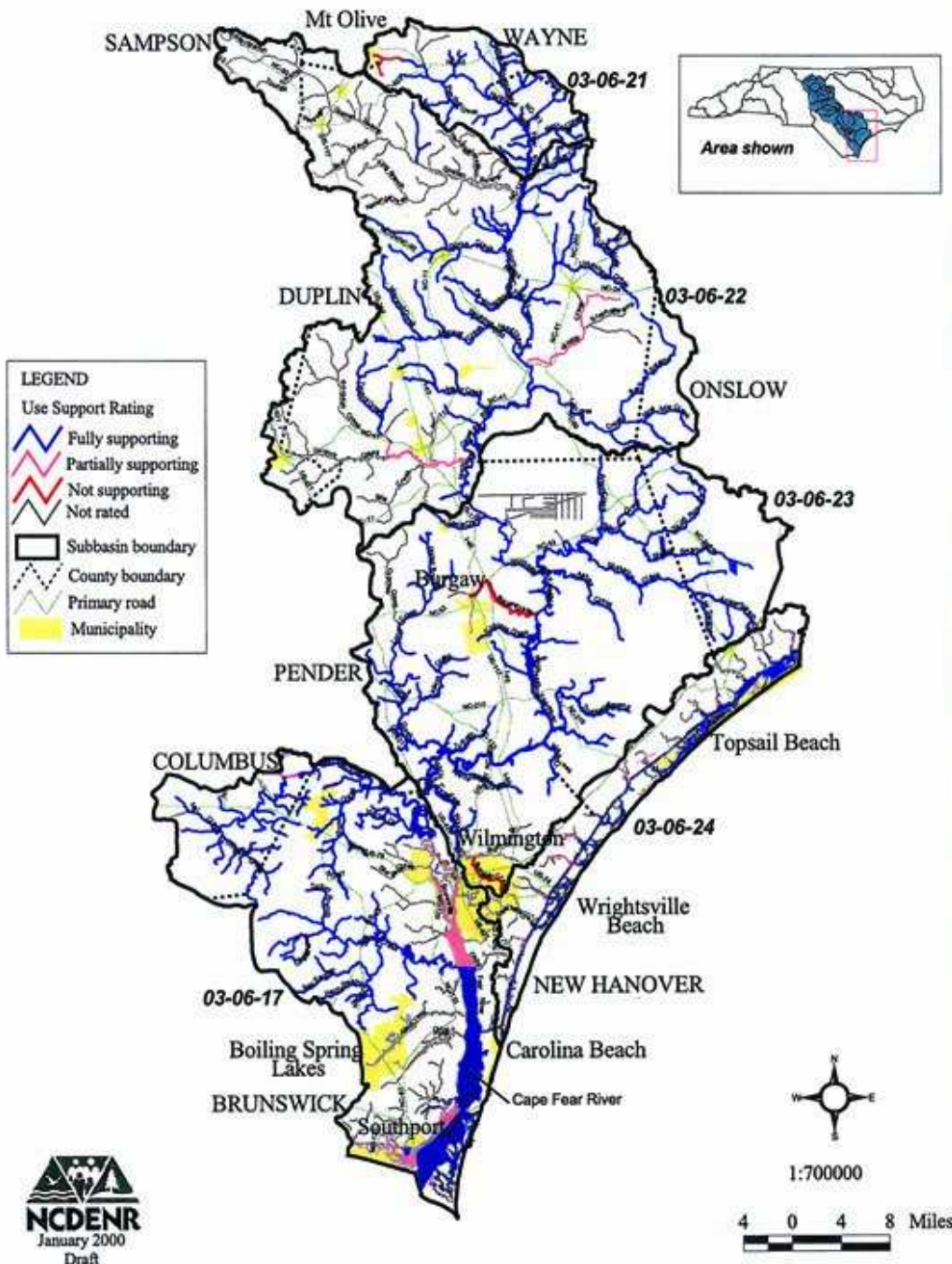
3.2 Methods

Each subbasin is addressed separately, with a description and map showing the LCFRP stations. This will be followed by a summary of the information published in the Cape Fear River Basinwide Water Quality Plan, July 2000 and use support ratings and discussion using the UNCW-AEL scheme for the 2003-2004 data.

Use Support in the Middle Cape Fear River Basin



Use Support in the Lower Cape Fear River Basin



3.3 Cape Fear River Subbasin 03-06-16

Location: Cape Fear River near Elizabethtown downstream to several miles below Lock and Dam #1

Counties: Bladen

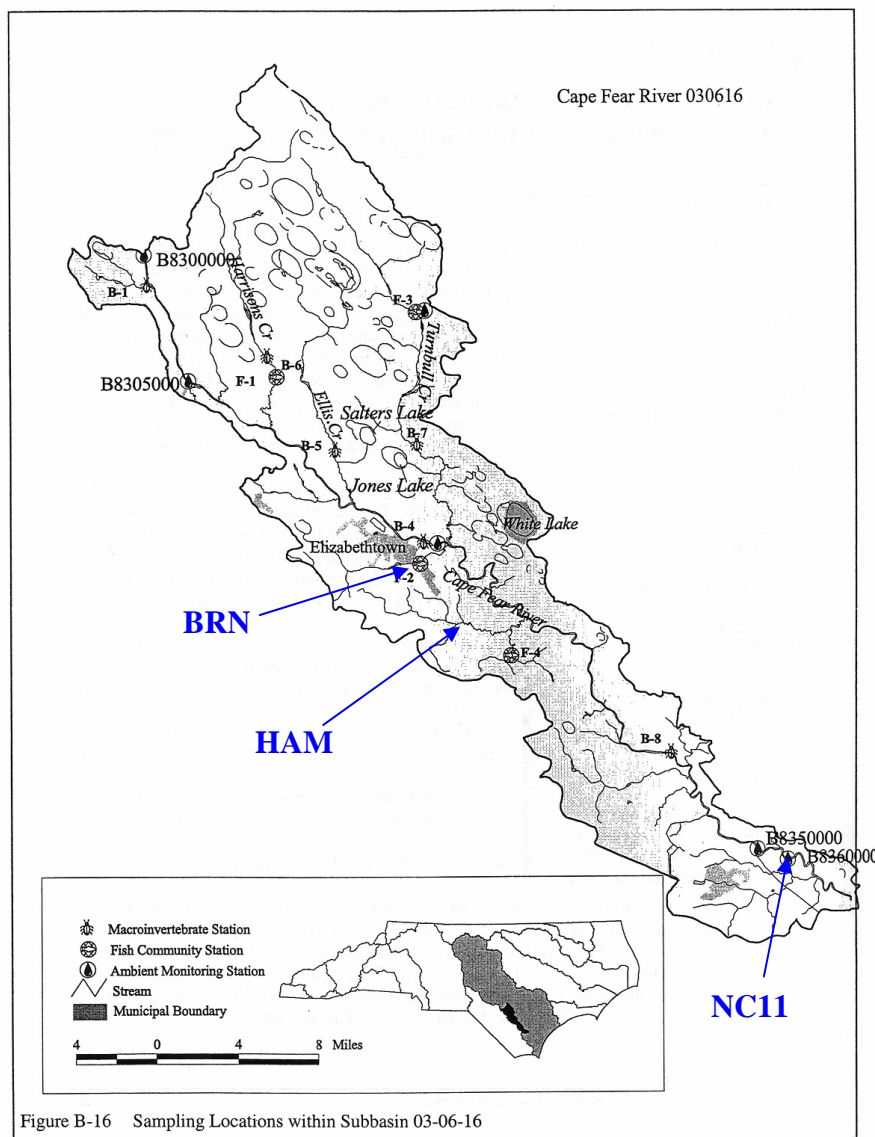
Water bodies: Cape Fear River

Municipalities: Elizabethtown

LCFRP monitoring stations (DWQ #):

BRN (B8340050), HAM (B8340200), NC11 (B8360000)

NC DWQ monitoring stations (DWQ #): NC11 (B8360000)



Use Support Ratings from NCDENR DWQ Basinwide Report, July 2000:

Fully Supporting:	240.8 miles
Partially Supporting:	0.0 miles
Not Supporting:	8.5 miles
Not Rated:	11.8 miles

The portion of the Cape Fear River within this subbasin is deep and slow moving. There are several natural lakes and streams that are tannin-stained with low pH blackwaters. Land use is mostly forest and marsh with some agriculture within the subbasin. There are eight permitted dischargers, mostly near Elizabethtown. Four of the largest dischargers, Veeder-Root, Smithfield Foods Incorporated in Tar Heel, Alamac Knit Fabrics in Elizabethtown, and Dupont of Fayetteville, discharge into the Cape Fear River (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Portions of Turnbull Creek and Harrisons Creek were considered partially supporting (PS) in the 1996 Basinwide Plan. Both are currently fully supporting (FS) and no longer on the state's 303(d) list. Brown's Creek (8.5 miles from source to Cape Fear River) is non supporting (NS) according to recent DWQ monitoring because of an impaired biological community. Urban non-point sources and sanitary sewer overflows from the City of Elizabethtown are possible sources of impairment. This stream is on the state's year 2000 303(d) list (NCDENR, DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Approximately 1% of the waters in this subbasin are impaired by non-point source pollution (mostly urban). All of the waters in this subbasin are affected by non-point sources. NCDENR, other state agencies and environmental groups have programs and initiatives underway to address water quality problems associated with non-point sources (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: NC11 since June 1995, BRN & HAM since February 1996

Sampling relevance: Represents water entering the Lower Cape Fear River watershed from the middle basin. There are also several concentrated animal operations within the area.



BRN - representative of small tributaries of the Cape Fear River



NC11 - main stem of Cape Fear River,
deep channel, freshwater
with slight tidal influence

The sites at Browns Creek (BRN) and North Carolina Highway 11 (NC11) were found to have a good quality rating for dissolved oxygen, meeting the North Carolina State Standard of 5.0 mg/L in all sampled months except at NC11 in August 2003 (4.7 mg/L). Hammonds Creek (HAM), a small channelized tributary, was rated as poor, with dissolved oxygen levels falling below 5.0 mg/L in four of the twelve sampled months (33% of the time). The lowest concentrations of dissolved oxygen at HAM were 3.6 mg/L, found in July 2003. The dissolved oxygen concentrations for Hammonds Creek are represented graphically in Figure 3.3.1.

All sites within this subbasin were found to have a good quality rating for chlorophyll *a* concentrations. The North Carolina State Standard for chlorophyll *a* of 40 µg/L was not exceeded at HAM, BRN, or NC11 during 2003-2004.

Fecal coliform bacteria concentrations were low at NC11, receiving a good quality rating with one sample over the NC State Standard for human contact waters of 200 CFU/100mL in 2003-2004. Browns Creek (BRN) received a fair quality rating for fecal coliform bacteria concentrations, exceeding the standard 17% of the time. At BRN fecal coliform bacteria concentrations were above 2,000 and 3,000 CFU/100 mL in March 2003 and November 2003, respectively. Hammonds Creek (HAM) was rated as poor quality for fecal coliform bacteria concentrations, exceeding the NC State Standard in 29% of samples. Fecal coliform bacteria concentrations were greater than 4,000 CFU/100mL in March 2003 at HAM (Figure 3.3.2).

Though there were elevated turbidity levels noted in the March 2003 sampling, all sites within this subbasin were rated as good quality for turbidity concentrations. The March 2003 concentrations at all three sites and May 2004 at NC11 were the only ones to exceed the 50 NTU North Carolina State Standard for turbidity. The concentrations for March 2003 were 85 NTU, 125 NTU, and 86 NTU for BRN, HAM, and NC11 respectively. The means for the 2003-2004 sampling period were 9 NTU (BRN), 11 NTU (HAM) and 25 NTU (NC11).

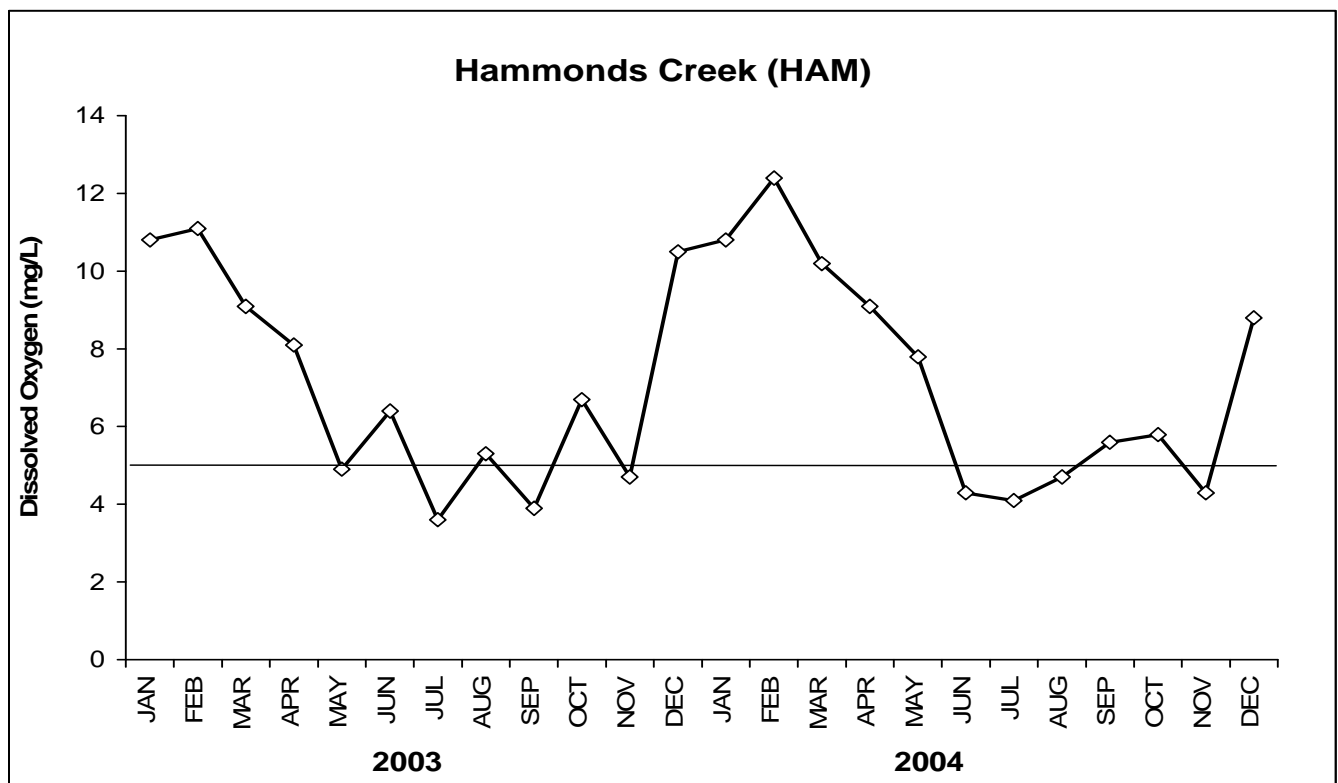


Figure 3.3.1 Dissolved oxygen concentrations (mg/L) for Hammonds Creek (HAM) showing the NC State Standard of 5.0 mg/L.

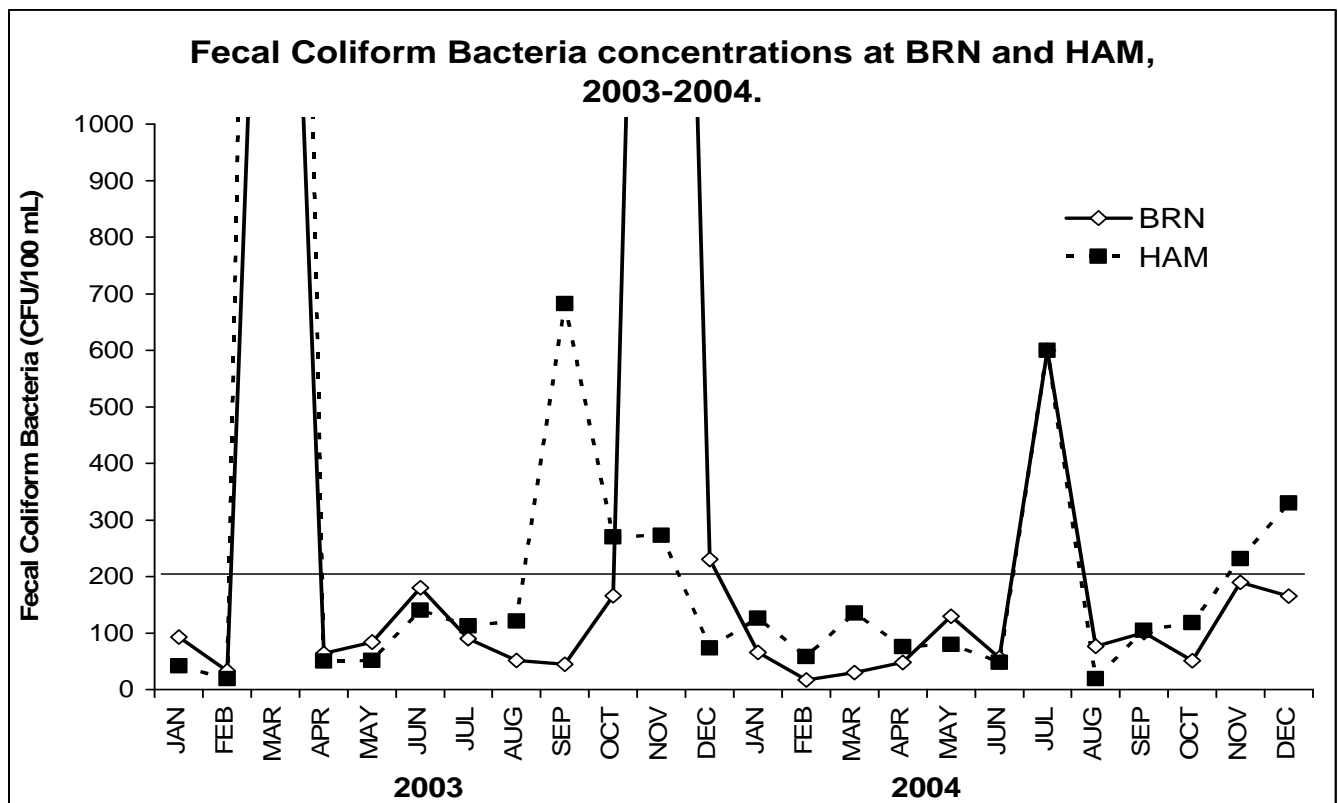


Figure 3.3.2. Fecal coliform bacteria concentrations (CFU/100mL) for Browns Creek (BRN) and Hammonds Creek (HAM). The line shows the NC State Standard for human contact waters of 200 CFU/100mL.

3.4 Cape Fear River Subbasin 03-06-17

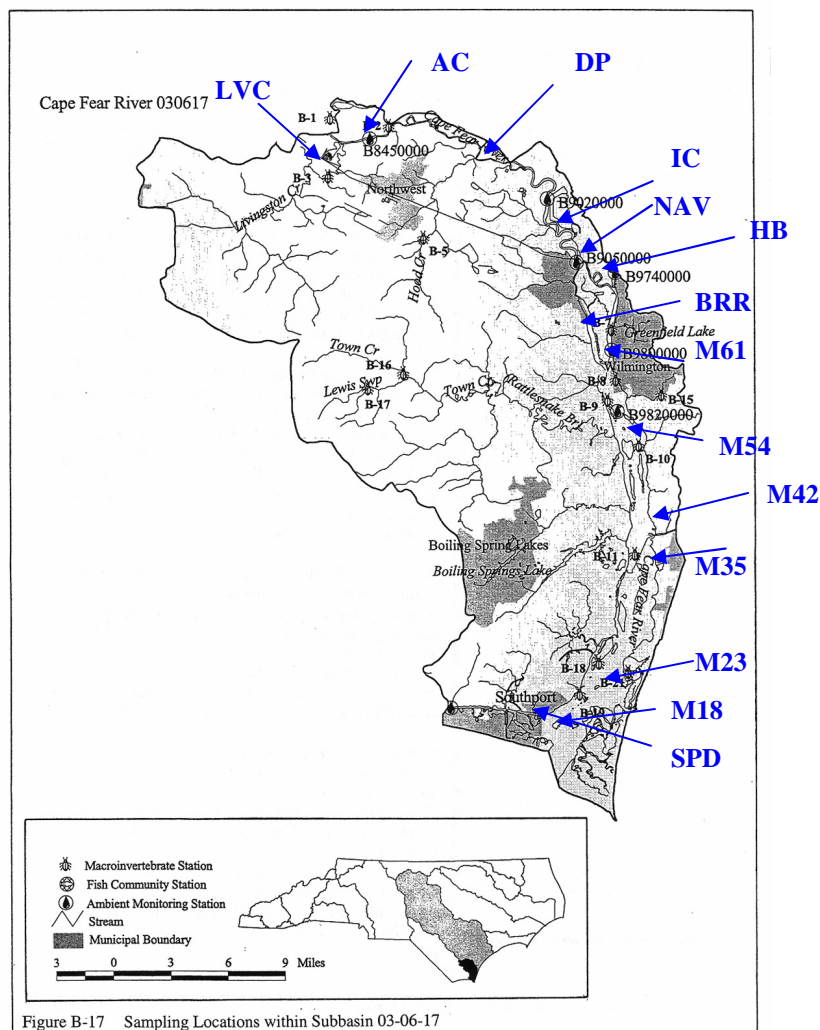
Location: Cape Fear River near Riegelwood, downstream to estuarine area near Southport
Counties: Columbus, Pender, Brunswick, New Hanover
Waterbodies: Cape Fear River and Estuary
Municipalities: Wilmington, Southport

LCFRP monitoring stations (DWQ #):

LVC (B8445000), AC (B8450000), DP (B8460000), IC (B9030000), NAV (B9050000), HB (B9050100), BRR (B9790000), M61 (B9750000), M54 (B9795000), M42 (B9845100), M35 (B9850100), M23 (B9910000), M18 (B9921000), SPD (B9980000)

DWQ monitoring stations:

NAV (B9050000), M61 (B9750000), M54(B9795000)



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting: 251.5 miles
Partially Supporting: 3.8 miles
Not Supporting: 0.0 miles
Not Rated: 65.5 miles

Estuarine Waters

Fully Supporting: 16,314 acres
Partially Supporting: 7,211 acres
Not Supporting: 0.0 acres
Not Rated: 925 acres

This subbasin is located in the outer coastal plain and in estuarine regions of the basin. Significant dischargers in this subbasin are the City of Wilmington and the Town of Southport. There are 49 permitted dischargers in the subbasin, half of which discharge directly into the Cape Fear River. The largest dischargers are International Paper, Wilmington North Side WWTP and Wilmington South Side WWTP (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Portions of Livingston Creek, the Cape Fear River and estuarine areas were identified as impaired in the 1996 Basinwide Water Quality Plan (NCDENR, DWQ). Currently Livingston Creek is listed as fully supporting (FS) and is no longer on the 303(d) list of impaired waters. The Cape Fear River is currently partially supporting (PS), because of an impaired biological community. The International Paper Board discharge and nonpoint source pollution are possible causes of impairment, and this segment of the river is on the state's year 2000 303(d) list. The Cape Fear River Estuary (5000 acres) is partially supporting (PS) and is on the state's year 2000 303(d) list. The cumulative impacts from WWTP discharges in the subbasin as well as nonpoint source pollution are suspected to be the significant contributors to the impairment. Swamp water drainage may also be a source of low dissolved oxygen (DO) waters feeding into the estuary. Possible sources of nonpoint source pollution include marinas, canal systems, and septic systems (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Approximately 45% of the waters in this subbasin are impaired by nonpoint source pollution. All the waters of the subbasin are affected by nonpoint sources. The 303(d) list approach will be to develop a TMDL (Total Maximum Daily Load) for this segment of the Cape Fear River because of low DO levels. Because of the nature of the river/estuary system in this portion of the basin, addressing water quality issues must not be limited to problems in impaired segments alone. Because this segment of the river and estuary are impaired, issuance of new and expanding discharges that would further increase the load of oxygen-consuming waste into these waters will be considered on a case by case basis (NCDENR, DWQ, Cape Fear River Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: most stations since 1995, all sampled since 1998

Sampling relevance: below point source dischargers and non-point source pollution



AC - representative of riverine system channel



HB – upper estuary, upstream of Wilmington



M35 – represents wide estuary

Sites rated as good quality for dissolved oxygen by concentrations the UNCW-AEL include: AC, M54, M42, M35, M23, and M18. The following sites were rated as fair quality for dissolved oxygen, with the percentage of samples not meeting the standard of 5.0 mg/L shown in parentheses: LVC (13%), DP (13%), IC (21%), NAV (13%), HB (17%), BRR (17%), M61

(13%). Dissolved oxygen concentrations are represented graphically for DP, NAV, HB and M61 in Figure 3.4.1. Dissolved oxygen levels often drop below the state standard during summer months.

All sites within this subbasin were found to be good quality in terms of chlorophyll *a* concentrations. None of the sampled locations exceeded the 40 µg/L North Carolina State Standard on any sample occasion.

All sites within this subbasin were rated as good quality for fecal coliform bacteria concentrations. No site exceeded the 200 CFU/100mL NC State Standard for human contact waters. Areas in the middle estuary at M35 down to mouth of the river can have harvestable populations of shellfish including oysters (*Crassostrea virginica*) and clams (*Mercenaria mercenaria*). The NC State fecal coliform bacteria standard for shellfishing states that the geometric mean cannot exceed 14 CFU/100mL and no more than 10% of samples may exceed 43 CFU/100mL. All of the LCFRP stations in shellfishing areas met the NC State standard.

For turbidity, the stations NAV and those upstream were evaluated using the NC State Standard for freshwater of 50 NTU while all stations downstream of NAV were evaluated with the NC State Standard for brackish waters of 25 NTU. The following stations were good quality for turbidity: LVC, DP, IC, NAV, M35, M23, M18, and SPD. The following sites were rated as fair quality for turbidity (percentage of samples below standard): AC (13%), HB (21%), BRR (17%), M61 (13%), M54 (25%), M42 (25%).

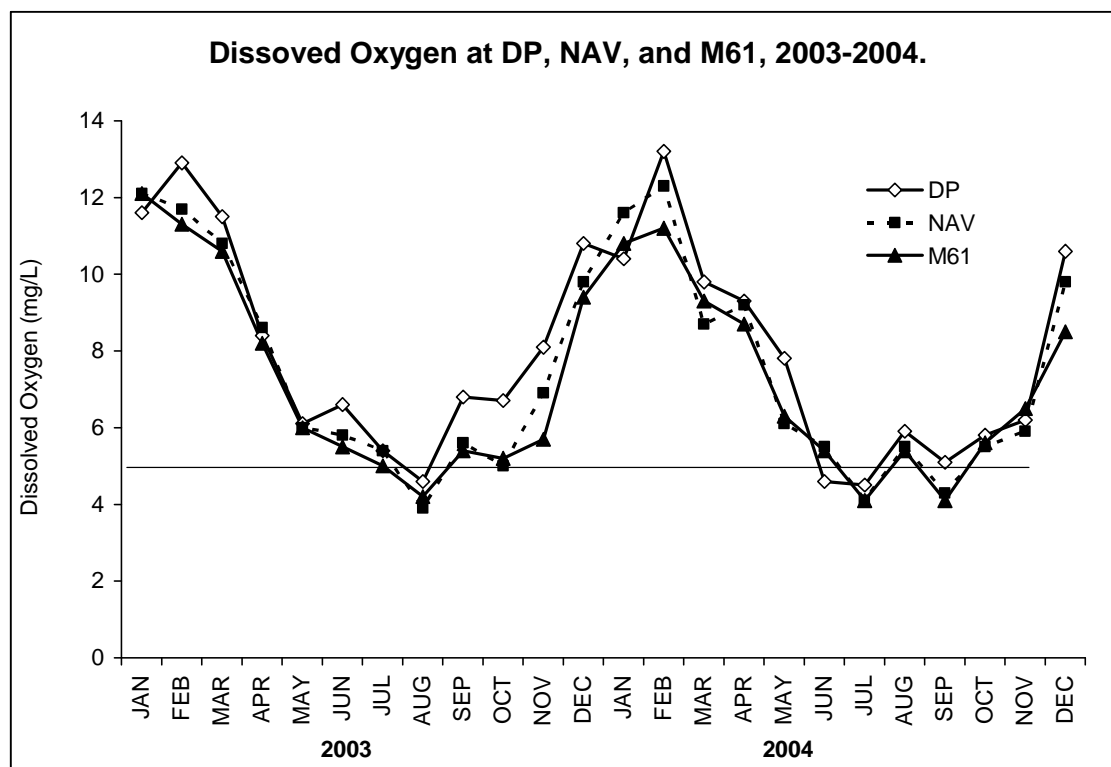
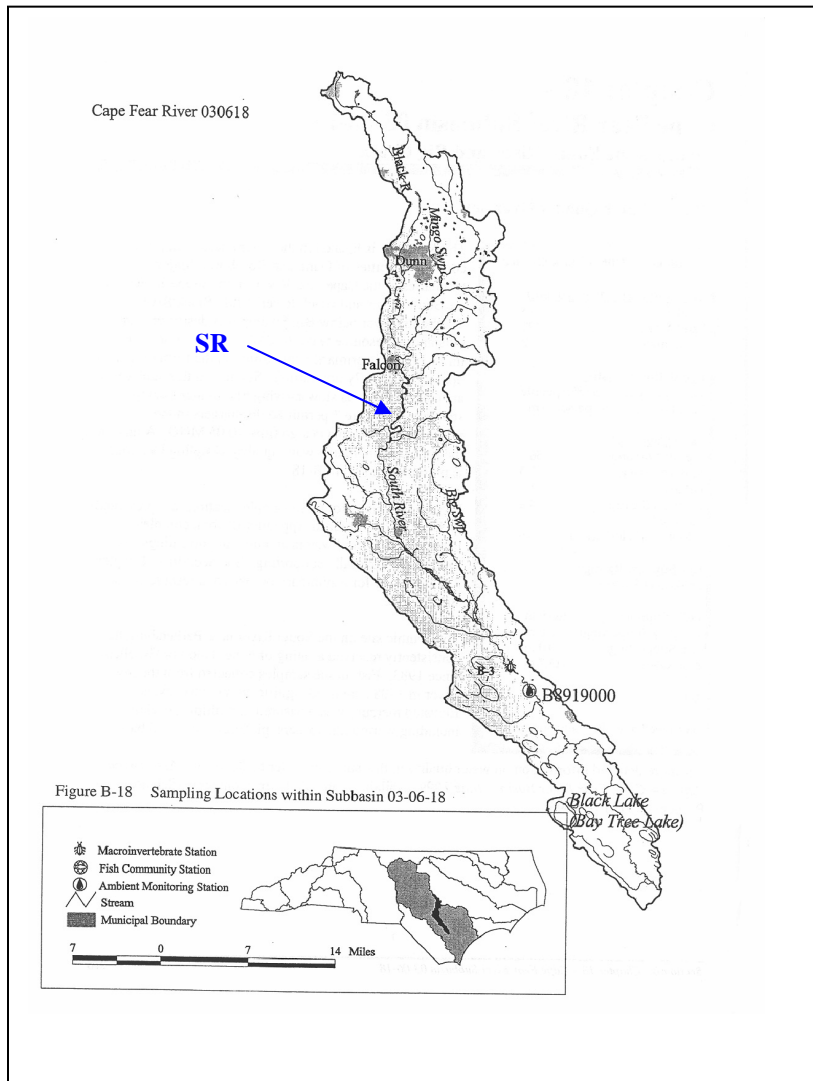


Figure 3.4.1 Dissolved oxygen concentrations (mg/L) for DP, NAV and M61 for 2003-2004. The solid line shows the NC State Standard of 5.0 mg/L.

3.5 Cape Fear River Subbasin 03-06-18

Location: South River headwaters above Dunn down to Black River
Counties: Bladen, Cumberland, Harnett, Johnston, Sampson
Waterbodies: South River, Mingo Swamp
Municipalities: Dunn, Roseboro

LCFRP monitoring stations (DWQ #): SR (B8470000)
DWQ monitoring stations: none



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting:	165.9 miles
Partially Supporting:	0.0 miles
Not Supporting:	0.0 miles
Not Rated:	113.7 miles

This subbasin is located on the inner coastal plain and includes South River which converges with the Great Coharie Creek to form the Black River, a major tributary of the Cape Fear River. Land use is primarily agriculture including row crops and concentrated animal operations. Most streams are slow moving black-water swamp streams. There are three permitted dischargers within this subbasin (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

The South River (7.2 miles from source to NC 13) and the Little Black River (from Dunn to I-95) were both rated as partially supporting (PS) in the 1996 plan. Neither river was sampled by DWQ because of low flow conditions, each is currently not rated (NR). Both remain on the state's year 2000 303(d) list. Portions of the South River are not impaired; however, because of fish consumption advisories, this 70.9-mile segment is on the 303(d) list (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000). All the waters of the subbasin are affected by non-point pollution sources.

Lower Cape Fear River Program Assessment

Data collection: since February 1996

Sampling relevance: Below City of Dunn, hog operations in watershed



SR – a slow black water tributary

South River (SR) was found to be poor quality for dissolved oxygen concentrations. The North Carolina State Standard of 5.0 mg/L was not met 54% of the time and the swampwater standard of 4.0 mg/L was not 50% of the time. The lowest levels were found in late summer and early fall (Figure 3.5.1).

This site was found to be good quality for chlorophyll *a*, with no samples exceeding the 40 µg/L North Carolina State Standard.

SR was rated as good quality for fecal coliform bacteria concentrations, exceeding the NC State Standard of 200 CFU/100mL in 8% of samples. The highest concentrations were in March 2003 (235 CFU/100mL) and November 2004 (240 CFU/100mL).

This site was found to be good quality in terms of turbidity, with no samples above the 50 NTU North Carolina State Standard.

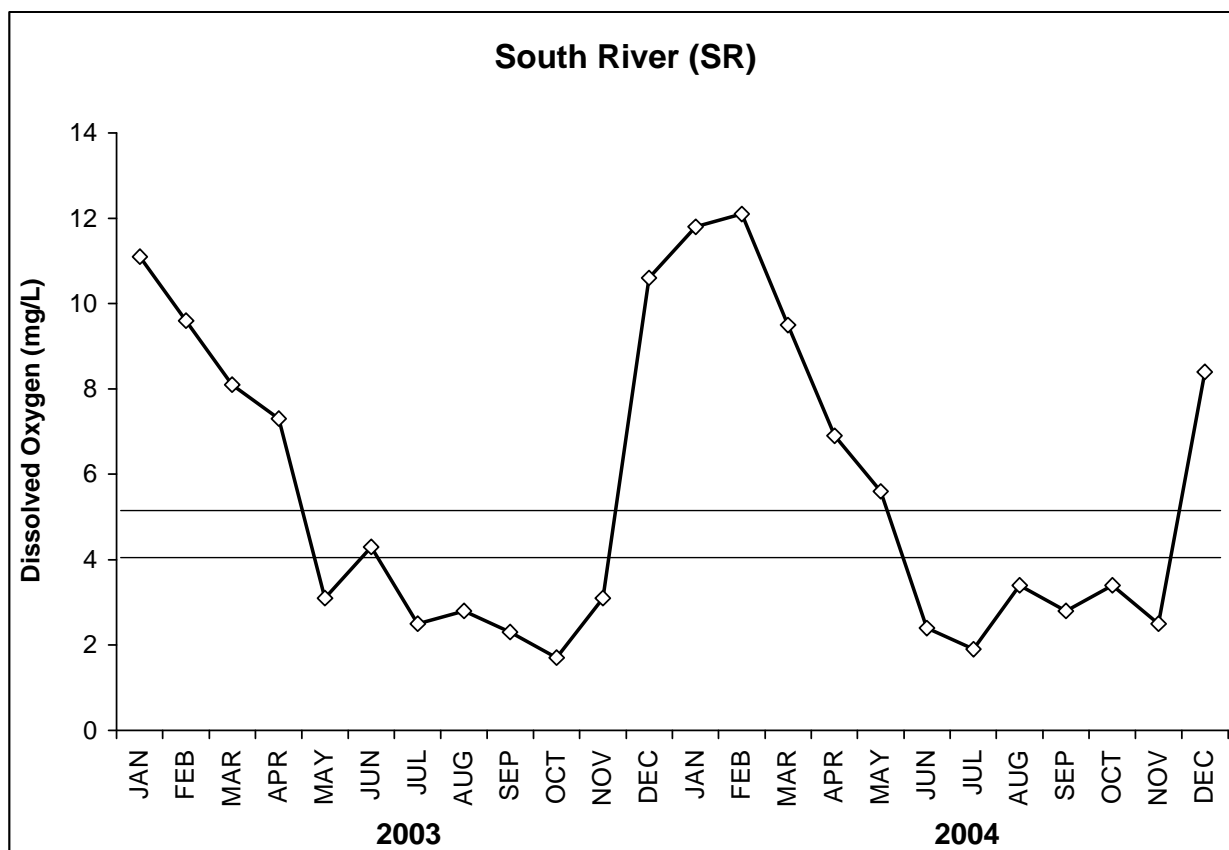


Figure 3.5.1 Dissolved oxygen concentrations (mg/L) for South River (SR) for 2003-2004. The lines show the NC State Standards of 5.0 mg/L and for swampwater of 4.0 mg/L.

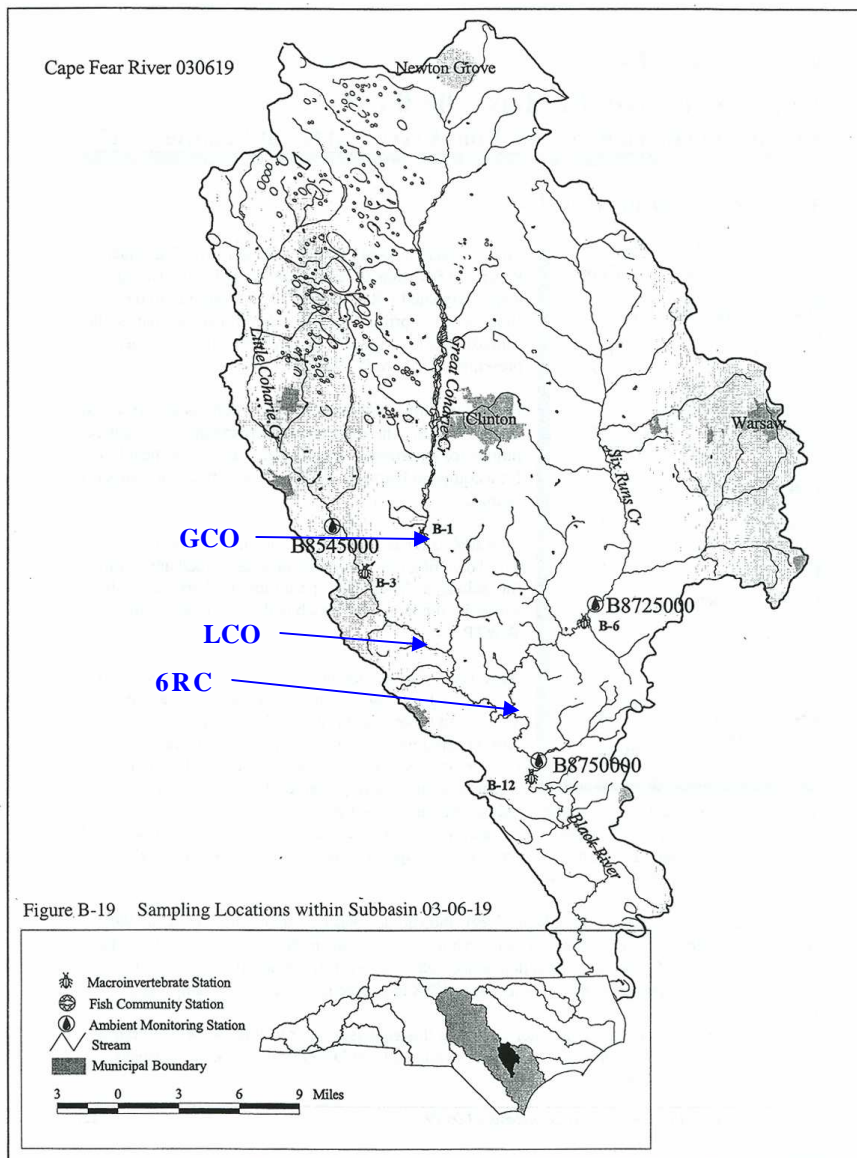
3.6 Cape Fear River Subbasin 03-06-19

Location: Three main tributaries of Black River near Clinton
Counties: Sampson
Waterbodies: Black River, Six Runs Creek, Great Coharie Creek,
Little Coharie Creek
Municipalities: Clinton, Newton Grove, Warsaw

LCFRP monitoring stations (DWQ #):

LCO (B8610001), GCO (B8604000), 6RC (B8740000)

DWQ monitoring stations: none



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting:	452.1 miles
Partially Supporting:	15.0 miles
Not Supporting:	0.0 miles
Not Rated:	40.2 miles

This subbasin is located in the coastal plain within Sampson County. Land adjacent to the Black River is primarily undisturbed forest. There is a very high concentration of hog farms within this subbasin. There are 7 permitted dischargers, the largest of which is the Town of Clinton (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Stewarts Creek (15.0 miles from source to Six Runs Creek) is currently partially supporting (PS) due to an impaired biological community. The Town of Magnolia discharges into a tributary, which eventually flows to Stewarts Creek downstream of Warsaw. The Magnolia WWTP has had problems with effluent toxicity and has been fined monthly during violations. Stewarts Creek is the only stream in the subbasin that is impaired and on the state's year 2000 303(d) list (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Portions of Great Coharie Creek, Little Coharie Creek, Six Runs Creek and Crane Creek were impacted during Hurricane Fran in 1996. These streams were also subject to massive desnagging (removal of fallen trees) operations after the storm. Benthic monitoring is recommended to determine the impacts of desnagging operations that remove important habitat in these waters (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: February 1996 to present

Sampling relevance: Concentrated animal operations (CAOs) within the watershed, reference areas for point and nonpoint source pollution



GCO - blackwater stream, drains riparian wetlands

Little Coharie Creek (LCO) and Six Runs Creek (6RC) were found to be good quality for dissolved oxygen (DO) concentrations. Great Coharie Creek (GCO) was rated as poor quality for dissolved oxygen concentrations, not meeting the standard of 5.0 mg/L in 38% of the samples. When evaluated using the swampwater standard of 4.0 mg/L, GCO was rated as fair quality, with 13% of samples below the 4.0 mg/L swamp water standard. The dissolved oxygen concentration values for GCO are represented graphically in Figure 3.6.1.

All sites within this subbasin were found to be good quality for chlorophyll a concentrations, fecal coliform bacteria concentrations and turbidity concentrations.

Nitrate levels were high in Six Runs Creek (6RC), exceeding 200 µg/L for 92% of the samples (Figures 3.6.2). Levels at or above 200 µg/L generally indicate problematic conditions in small tributaries such as 6RC. These levels are above the concentrations known to lead to ATP increases, bacterial increases and increased biochemical oxygen demand (BOD) in experiments using water from black water streams (Mallin et al. 2001, Mallin et al. 2002).

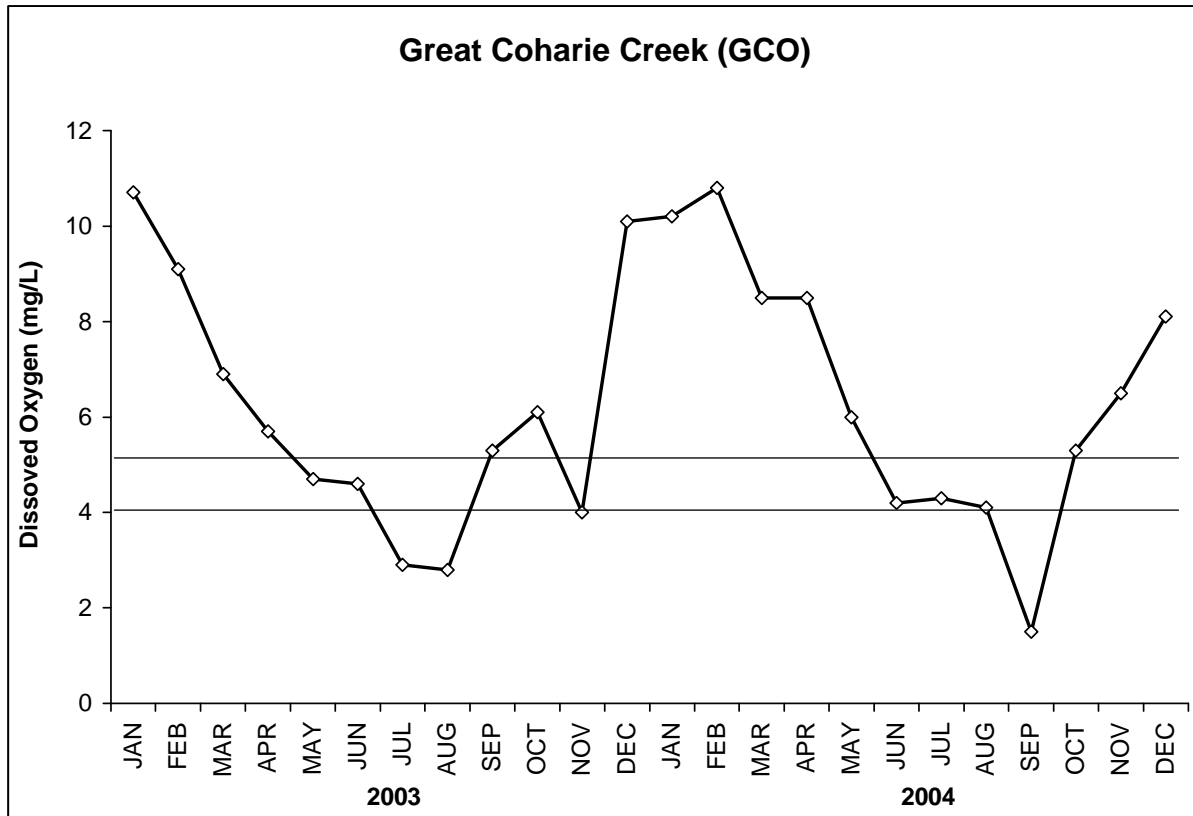


Figure 3.6.1 Dissolved oxygen concentrations (mg/L) for GCO during the 2003-2004 monitoring period. The lines show the NC State Standards of 5.0 mg/L and 4.0 mg/L swamp water.

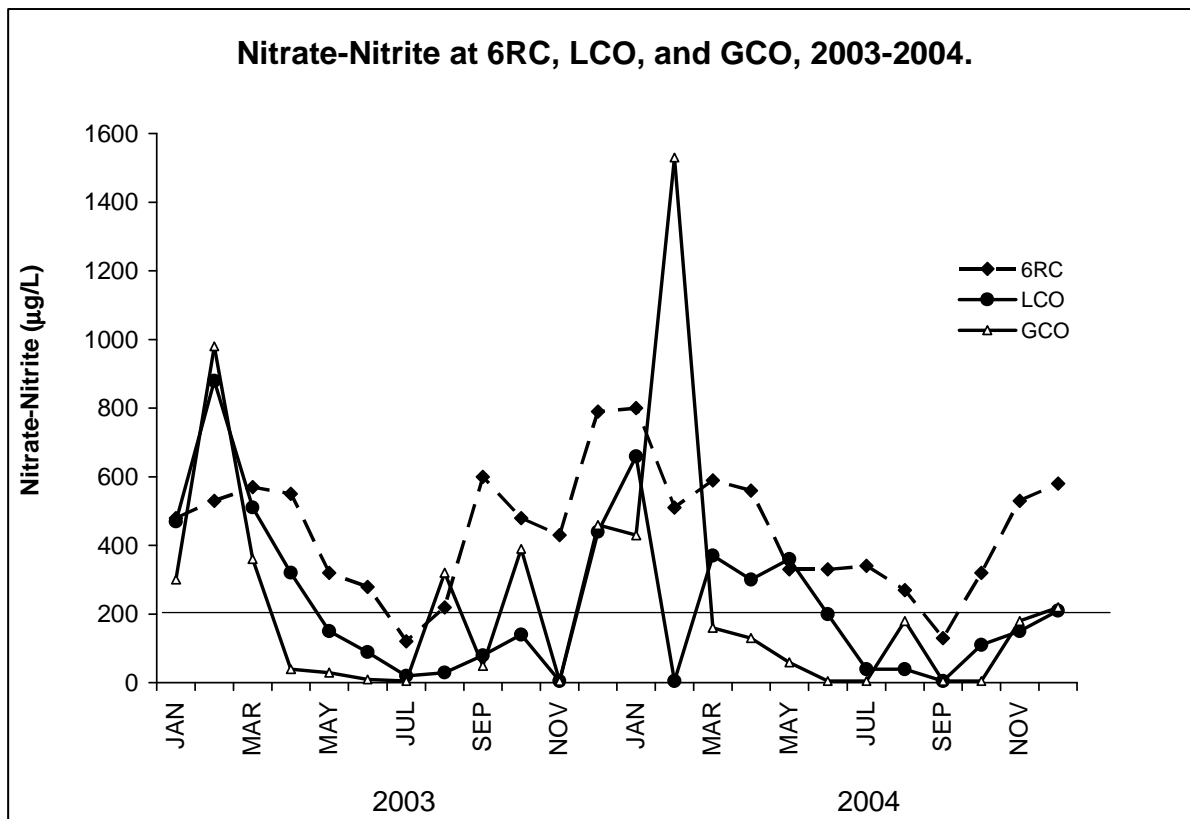


Figure 3.6.2 Nitrate concentrations (µg/L) for 6RC, LCO, and GCO during 2003-2004. The line shows level considered problematic in black water streams.

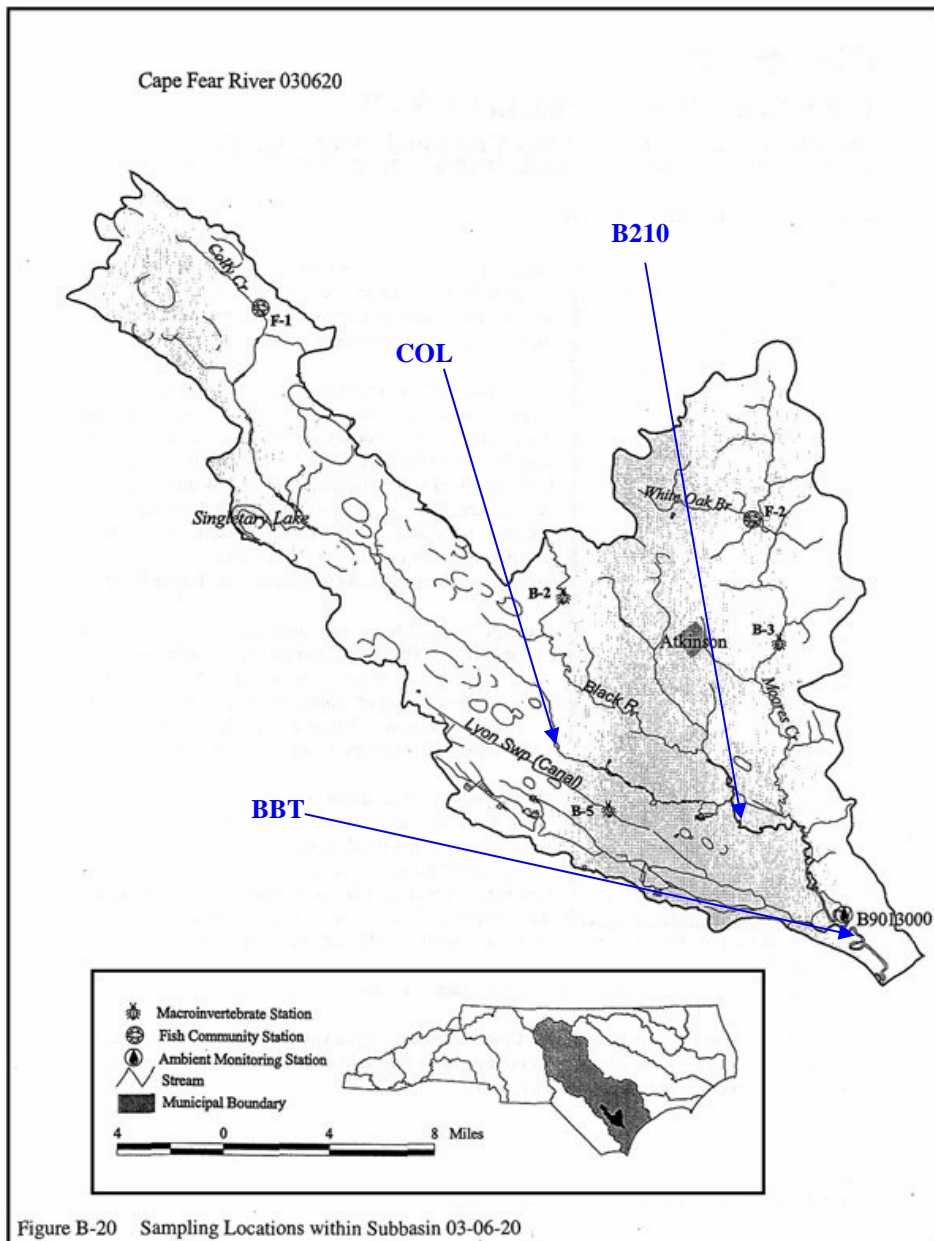
3.7 Cape Fear River Subbasin 03-06-20

Location: Tributaries of the Black River near confluence with the Cape Fear River
Counties: Pender
Waterbodies: Black River, Colly Creek, Moores Creek
Municipalities: Town of White Lake, Currie, Atkinson

LCFRP monitoring stations (DWQ #):

COL (B8981000), B210 (B9000000), BBT (none)

DWQ monitoring stations: none



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting:	142.5 miles
Partially Supporting:	0.0 miles
Not Supporting:	0.0 miles
Not Rated:	35.7 miles

This subbasin is located on the coastal plain in Pender County. The only permitted discharger within the subbasin is White Lake WWTP. The characteristics of streams in this area include, typically, low geographic relief, low pH black waters and a tendency for all but the largest rivers to stop flowing in the summer. The Black River in this area has been classified as Outstanding Resource Waters (ORW) (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Agriculture is the major land use with non-point source pollution the major anthropogenic factor affecting the surface waters. Biological rating resulted in no streams being classified as impaired. The water quality of this subbasin appears to be generally good. Due to the lack of flow in summer months, DWQ water quality monitoring assessments of tributaries were based on winter sampling (NCDENR DWQ Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: February 1996 to present

Sampling relevance: Colly Creek is a pristine swamp reference site, B210 and BBT are middle and lower Black River sites



COL – blackwater stream, drains swamp area, very low pH



B210 - Black River at Hwy 210

Colly Creek was rated as good quality for dissolved oxygen concentrations when using swamp water standard and rated as fair using regular standard. B210 and BBT were both rated as fair quality using the swamp water (13%, 13%) and regular standards (25%, 25%). This area is affected by swamp water inputs and may have lower dissolved oxygen concentrations as a result of the naturally low DO levels in swamp water.

Chlorophyll *a* concentrations were low for each site within this subbasin and rated as good quality. No single sample exceeded the 40 µg/L North Carolina State Standard.

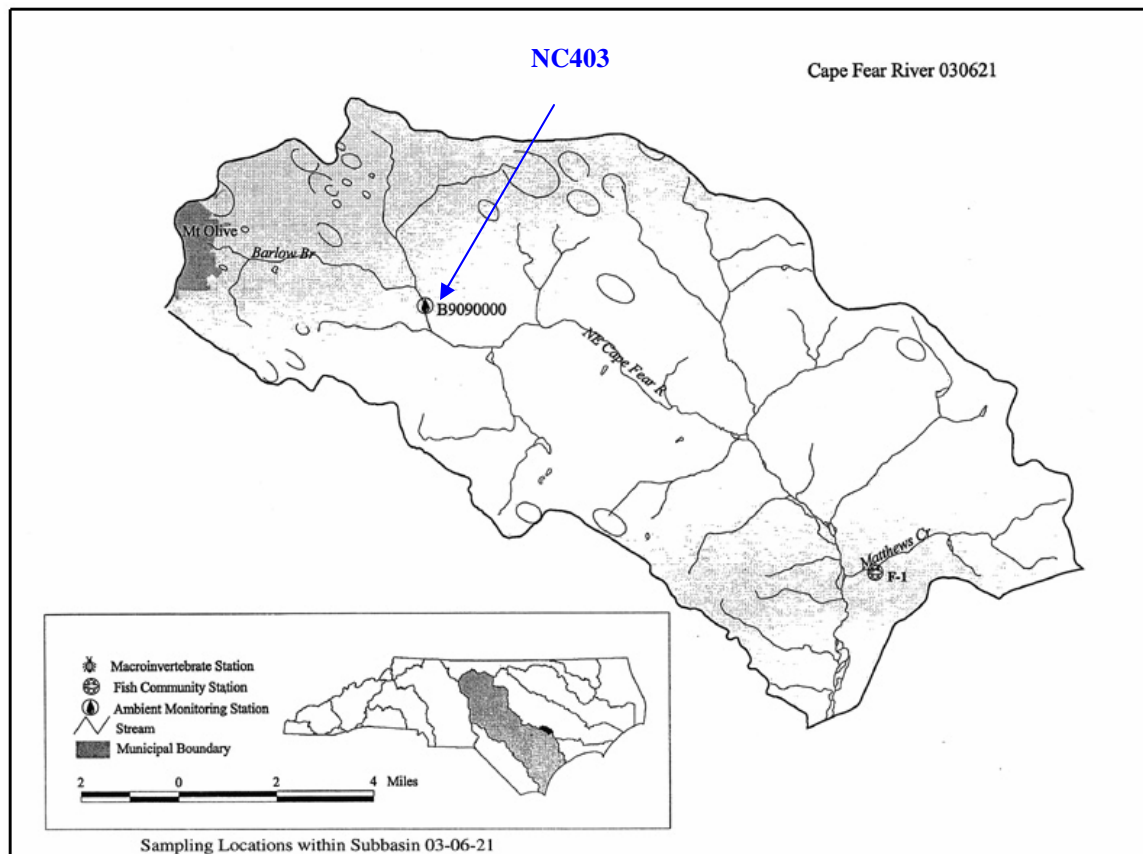
Fecal coliform bacteria concentrations were generally low, and COL and B210 were good quality. No single sample was above the NC State standard for human contact (200 cfr/100 mL). BBT samples were not analyzed for fecal coliform bacteria.

All three sites were rated as good quality for turbidity levels, not exceeding the North Carolina State Standard of 50 NTU.

3.8 Cape Fear River Subbasin 03-06-21

Location: Headwaters of NE Cape Fear River below Mount Olive
Counties: Duplin, Wayne
Waterbodies: Northeast Cape Fear River
Municipalities: Mount Olive

LCFRP monitoring stations (DWQ#): NC403 (B9090000)
DWQ monitoring stations: NC403



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting:	69.3 miles
Partially Supporting:	0.0 miles
Not Supporting:	4.3 miles
Not Rated:	6.8 miles

Significant dischargers in this subbasin are Mount Olive Pickle Company and the Town of Mount Olive. DWQ biological assessment sampling resulted in no impaired rating for streams in this subbasin.

Portions of the Northeast Cape Fear River and Barlow Branch were identified as impaired in the 1996 Basinwide Water Quality Plan. The discharge from Mount Olive Pickle Company was the cause of impairment. Chloride levels exceeded the water quality limit in 48% of the samples from 1993 to July 1996, at Northeast Cape Fear River at SR 1937 approximately 2.7 miles from discharge source. The ambient water quality station was relocated approximately 5.1 miles downstream in 1996 to the NC403 site. The ambient station data at NC 403 has not indicated high chloride levels. Currently the Northeast Cape Fear River (3.3 miles from source to SR 1937) and Barlow Branch (1 mile) are not supporting (NS) (NCDENR, DWQ, Cape Fear River Basinwide Water Quality Plan, July 2000).

The Mount Olive Pickle Company discharges chlorides above permitted levels into Barlow Branch before it joins the Northeast Cape Fear River. The Mount Olive Pickle Company was given a variance from the state surface water quality standard for chloride (230mg/L) in 1996. They have met the requirements of the variance to date, and have reduced water usage and salt usage (NCDENR, DWQ, Cape Fear River Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: June 1997 – present

Sampling relevance: Below Mount Olive Pickle Plant



NC403 - slow moving headwaters of
NE Cape Fear River

The NC403 site was found to be poor quality for dissolved oxygen concentrations, not meeting the NC State Standard of 5.0 mg/L in 58% of all samples. Even when using the NC swamp water standard of 4.0 mg/L, NC403 was found to be poor quality, not meeting the standard 50% of the time. The dissolved oxygen levels were often below 1.0 mg/L in the summer months (Fig. 3.8.1).

NC403 was found to be good quality in terms of chlorophyll *a*, yet there is very high aquatic macrophyte biomass present, almost clogging the waterway. As we have noticed at several of our stations over the years, Chlorophyll *a*, a measurement of phytoplankton biomass, and often used as an indicator of eutrophic conditions, is not always adequate to determine problematic conditions with regard to aquatic flora.

Fecal Coliform Bacteria levels were rated as good quality at NC 403, with one sample exceeding the NC State standard for human contact (200 CFU/100 mL).

NC403 was found to be good quality for turbidity, with no single sample exceeding the standard of 50 NTU during the 2003-2004.

UNCW researchers are concerned that elevated nitrate levels are periodically found at this site. Nitrate-N concentrations >500 µg/L occurred for 21% of the samples at NC403 during the 2003-2004. These levels are likely to lead to algal blooms and excessive aquatic macrophyte growth. High total phosphorus (TP) concentrations occur at times (>500 µg/L), which UNCW scientists find can stimulate increased biochemical oxygen demand (BOD) and lead to lower dissolved oxygen levels (Mallin et al. 2002). Nutrient concentrations are shown graphically for NC403 in Figure 3.8.2.

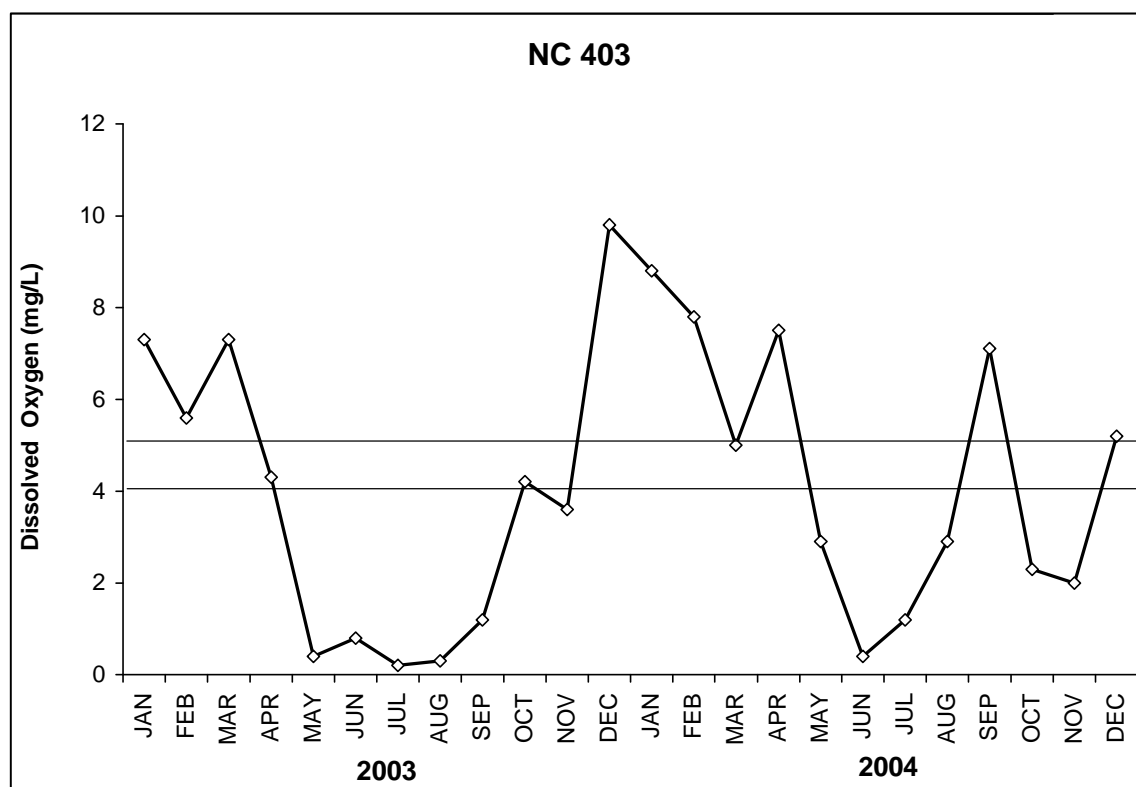


Figure 3.8.1 Dissolved oxygen concentrations (mg/L) at NC403 for 2003-2004. The lines show the NC State Standard of 5.0 mg/L and swamp water standard of 4.0 mg/L.

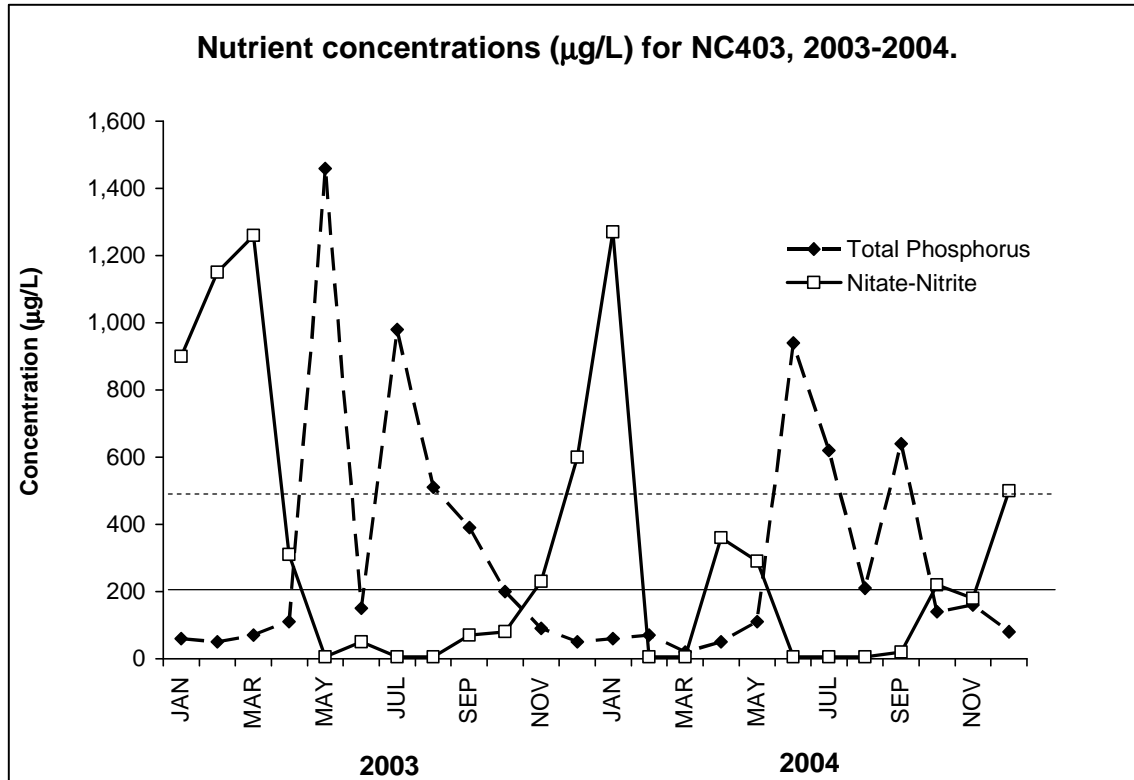


Figure 3.8.2 Nutrient concentrations ($\mu\text{g/L}$) at NC403 for 2003-2004. Dashed line represents problematic levels for Total Phosphorus ($500 \mu\text{g/L}$) and full line represents problematic levels for Nitrate-Nitrite ($200 \mu\text{g/L}$).

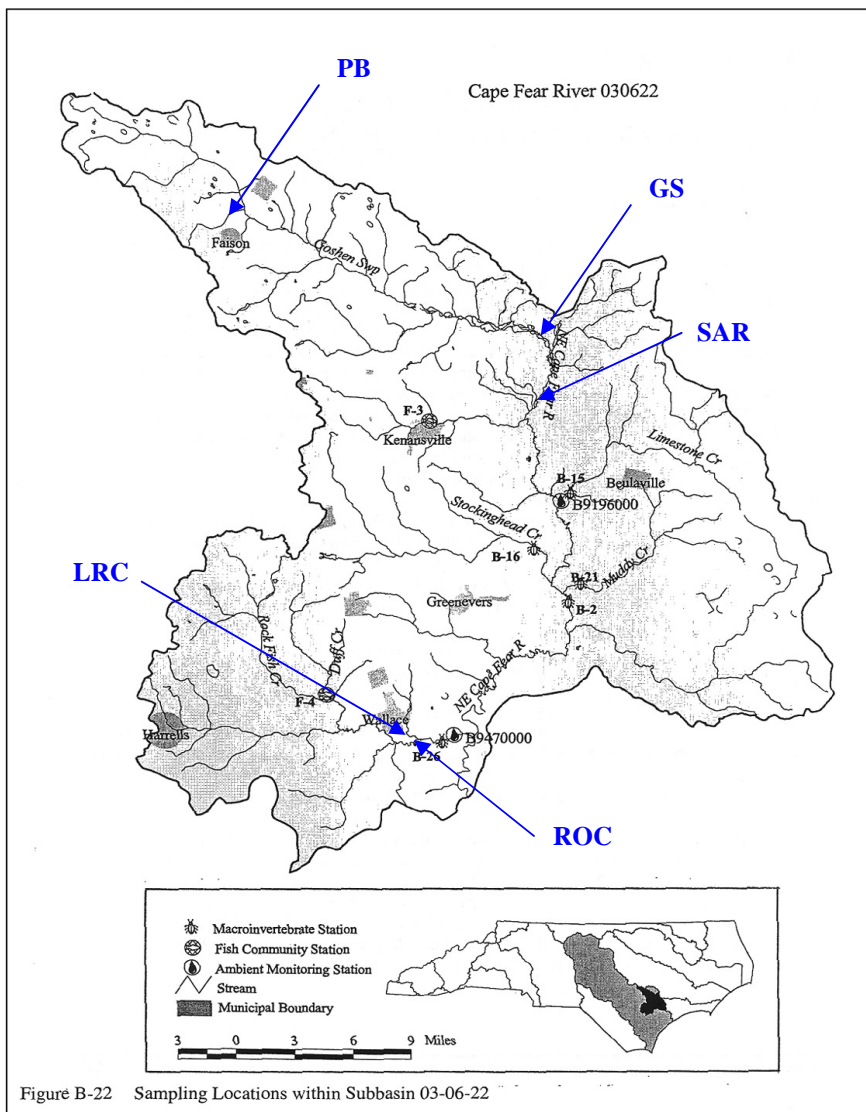
3.9 Cape Fear River Subbasin 03-06-22

Location: NE Cape Fear River and tributaries in the vicinity of Kenansville
Counties: Duplin
Waterbodies: Northeast Cape Fear River, Rockfish Creek
Municipalities: Beulaville, Kenansville, Rose Hill and Wallace

LCFRP monitoring stations (DWQ #):

PB (B9130000), GS (B9191000), SAR (B9191500), LRC (9460000)
ROC (B9430000)

DWQ monitoring stations: none



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting:	283.3 miles
Partially Supporting:	22.7 miles
Not Supporting:	0.0 miles
Not Rated:	208.2 miles

This subbasin contains the towns of Beulaville, Kenansville, Rose Hill, and Wallace. Most of the watershed is agricultural, including row crops and a dense concentration of animal operations (poultry and swine). The largest discharger is Stevecoknit Fabrics. Other large dischargers include Guilford Mills, Swift-Eckrich/Butterball and the town of Wallace (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Goshen Swamp and Panther Creek were not supporting (NS) in the 1996 plan because of high chloride discharge from Dean Pickle and Specialty Products. Discharge flows into a low flow tributary of Panther Creek before entering Goshen Swamp. Dean Pickle and Specialty Products was given a variance for chloride levels and has met that variance to date. Goshen Swamp and Panther Creek were not sampled during recent DWQ monitoring because of low flow conditions. These two streams are currently not rated (NR) (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Rockfish Creek (7.2 miles SR 1165 to Northeast Cape Fear River) was partially supporting (PS) in the 1996 plan. Currently, 8.7 miles (from Swift-Eckrich to Little Rockfish Creek) are partially supporting (PS) because of habitat degradation. The 3.8-mile segment from Little Rockfish Creek to the Northeast Cape Fear River is fully supporting (FS). Desnagging operations after Hurricane Fran removed important habitat for macroinvertebrates and fish in these waters. Point source dischargers may contribute to the habitat degradation. These waters are on the state's year 2000 303(d) list (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Muddy Creek (14.0 miles from the source to Northeast Cape Fear River) was not rated in 1993 because of its small size. The stream is significantly larger due to changes associated with Hurricane Fran in 1996. The stream is partially supporting (PS) according to recent DWQ monitoring due to nonpoint sources. The watershed contains many hog operations. This stream is on the state's year 2000 303(d) list (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: February 1996 to present

Sampling relevance: Below point and non-point source discharges



PB – slow moving swamp-like
Stream



ROC - Rockfish Creek below
Wallace

For the Dissolved Oxygen standard of 5.0 mg/L, LRC and ROC were good quality, and PB (25%) and SAR (21%) were found to be fair quality. PB was also found to be fair quality if measured by the swamp water standard of 4.0 mg/L, not meeting the standard 21% of the time. SAR was considered good quality if measured by the 4.0 mg/L swamp water standard. One site, GS was found to be poor quality for dissolved oxygen, not meeting the standard of 5.0 mg/L 46% of the time. Even when considering this site with the swamp water standard of 4.0 mg/L, it is found to be poor quality, not meeting the standard 42% of the time. The dissolved oxygen concentrations for GS are shown graphically in Figure 3.9.1.

For Chlorophyll a concentrations all sites were rated as good quality. PB had the very high concentration of 103 µg/L in July 2004.

For fecal coliform bacteria concentration, using the NC State standard of 200 CFU/100 mL for human contact, SAR was rated good while ROC (13%), GS (17%) and LRC (17%) were rated as fair. PB was rated as poor having exceeded the standard in 29%

of the samples. Fecal coliform bacteria concentrations are shown graphically for PB in Figure 3.9.2.

All sites were rated as good quality for turbidity concentrations. Mean turbidity levels were less than 20 NTU for all sites within this subbasin for the 2003-2004.

Stations PB and ROC both displayed high total phosphorus concentrations (Figure 3.9.3). High phosphorus levels are known to significantly increase bacterial concentration and biochemical oxygen demand (BOD) levels. Stations SAR, PB, LRC and ROC had elevated levels of nitrate+nitrite ($200\text{ }\mu\text{g/L}$) in greater than 25% of the samples, giving them a poor rating (Figure 3.9.4). High nitrate levels have been known to lead to algal bloom formation (Mallin et al. 2001, Mallin et al. 2002).

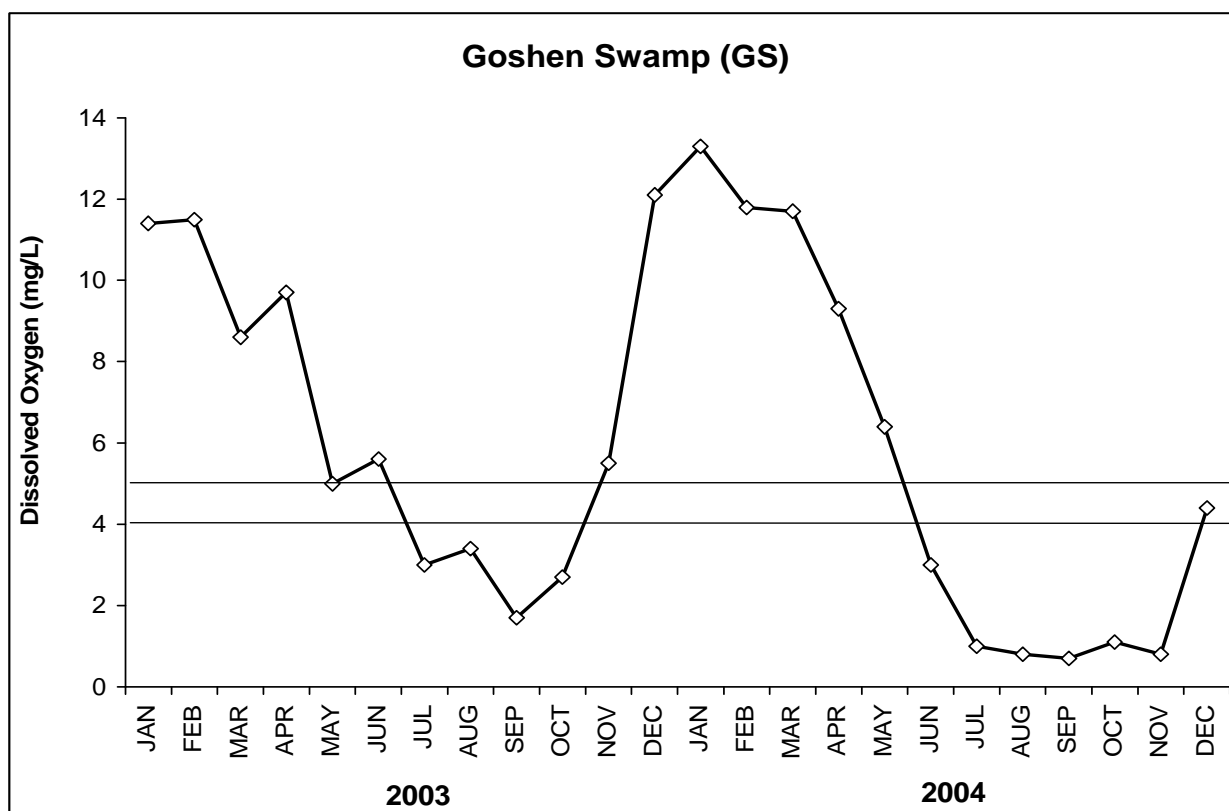


Figure 3.9.1 Dissolved oxygen concentrations (mg/L) for 2003-2004. The lines show the NC State Standard for dissolved oxygen of 5.0 mg/L and 4.0 mg/L.

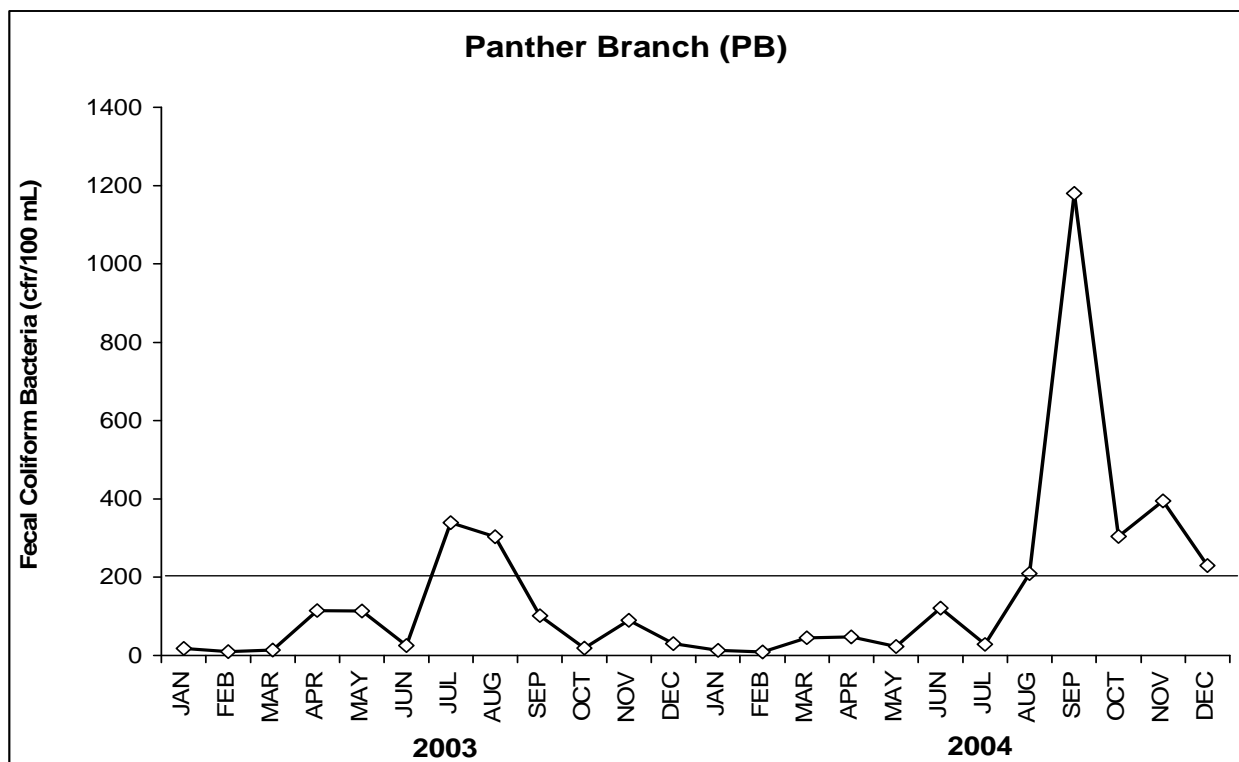


Figure 3.9.2 Fecal coliform bacteria concentrations (CFU/100mL) for the 2003-2004 at PB. The line shows the NC State Standard for human contact of 200 CFU/100mL.

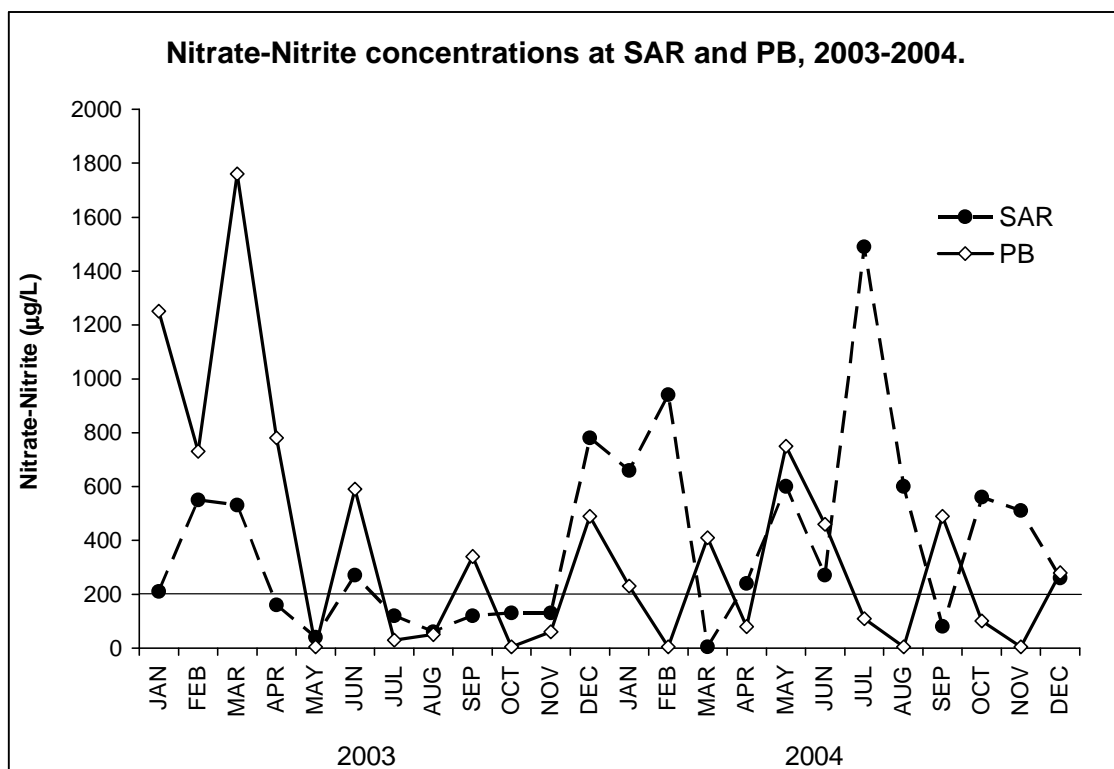


Figure 3.9.3 Nitrate-Nitrite concentrations (µg/L) at SAR and PB for 2003-2004.

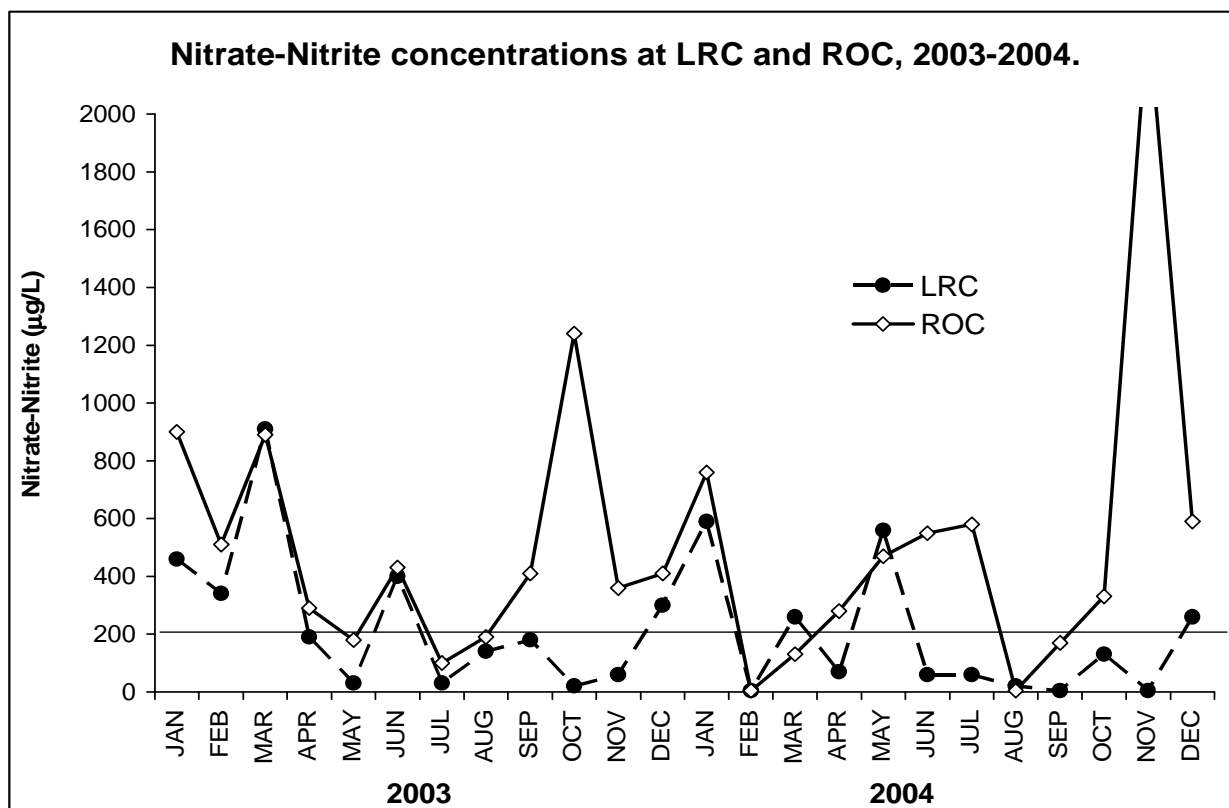


Figure 3.9.4 Nitrate-Nitrite concentrations ($\mu\text{g/L}$) at LRC and ROC for 2003-2004.

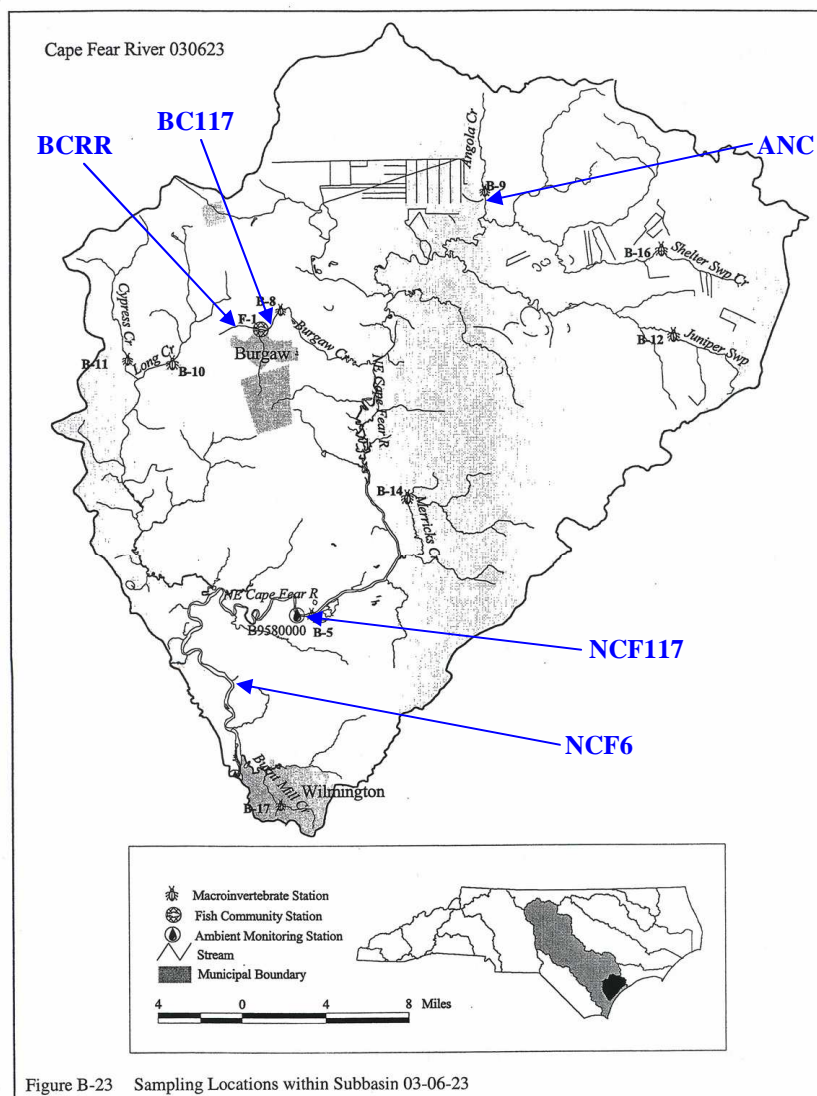
3.10 Cape Fear River Subbasin 03-06-23

Location: Area near Burgaw and Angola swamp
Counties: Pender
Waterbodies: Northeast Cape Fear River, Burgaw Creek
Municipalities: Burgaw

LCFRP monitoring stations (DWQ #):

ANC (69), BCRR (82), BC117 (83), NCF117 (84), NCF6 (85)

DWQ monitoring stations: NCF117



Use Support Ratings from NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000:

Freshwater Streams

Fully Supporting:	304.1 miles
Partially Supporting:	0.0 miles
Not Supporting:	14.3 miles
Not Rated:	37.5 miles

This subbasin is located in the outer coastal plain and contains the Town of Burgaw. Most streams in this area are slow flowing blackwater streams, and many dry up or stop flowing during the summer. Much of the subbasin is undeveloped and included in either the Holly Shelter Game Refuge or the Angola Bay Game Refuge (NCDENR, DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

There are six permitted dischargers in the subbasin, with the largest dischargers being Occidental Chemical, Thorn Apple Valley, and Burgaw WWTP. Ambient chemistry data show average nutrient levels in the Northeast Cape Fear River at US 117 to be lower than more upstream river sites. Biological rating resulted in impaired ratings for four of the seven stream segments. Benthic macroinvertebrate data showed fairly stable water quality for most of the subbasin, exceptions include Burgaw Creek below WWTP, and Burnt Mill Creek in Wilmington, both of which were rated poor (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Portions of Burnt Mill Creek and Burgaw Creek are currently rated as impaired according to recent DWQ monitoring. Burnt Mill Creek (4.8 miles from source to Smith Creek) was not supporting (NS) in the 1996 plan and is currently not supporting (NS) because of impaired biological community. Instream habitat degradation associated with urban nonpoint sources and channel dredging is a possible cause of impairment. This stream is on the state's year 2000 303(d) list (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Burgaw Creek (9.5 miles from Osgood Canal to the Northeast Cape Fear River) was not supporting (NS) in the 1996 plan, and is currently non-supporting (NS) due to impaired biological community. Instream habitat degradation associated with urban nonpoint sources is a possible cause of impairment. There are indications of excessive nutrients in this stream, and fecal coliform bacteria are also noted as a problem parameter. Failing septic systems have been noted in this watershed as well. The stream is channelized and has been adversely impacted by desnagging activities after Hurricane Fran. This stream is on the state's year 2000 303(d) list (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, July 2000).

Lower Cape Fear River Program Assessment

Data collection: NCF117 & NCF6 since June 1995, others from February 1996

Sampling relevance: point and non-point source dischargers



ANC - Angola Creek



BC117 - Burgaw Canal at US 117



NCF117 - Northeast Cape Fear River at
at US117

Four of five sites within this subbasin were rated as poor quality in terms of dissolved oxygen concentrations using the 5.0 mg/L standard. BC117 was the exception, rated as fair quality, not meeting the 5.0 mg/L standard in 17% of sampled months. NCF117 and NCF6 were both found to be poor quality, not meeting the standard in 46% of samples. BCRR was found to be poor quality, not meeting the standard 42% of the time. ANC was also found to be poor quality, not meeting the standard 50% of the time. All sites were also rated using the NC swamp water standard of 4.0 mg/L. ANC (46%), BCRR (25%) and NCF117 (33%) were rated poor quality, and NCF6 (13%) was rated fair. Dissolved oxygen concentrations are shown graphically for the four sites found to be poor quality in Figure 3.10.1 and Figure 3.10.2.

All sites in this subbasin were rated as good quality for chlorophyll *a* concentrations. Means for 2003-2004 were all less than 2 µg/L, well below the NC State Standard of 40 µg/L.

For Fecal Coliform Bacteria, two sites, NCF117 and NCF6 were rated as good quality. ANC was rated as fair quality, exceeding the human contact water (200 CFU/100mL) standard 13% of the time. BC117 and BCRR were rated as poor quality, exceeding the standard 46% and 38% of the time, respectively. Fecal coliform bacteria concentrations for BCRR and BC117 are shown graphically in Figure 3.10.3.

For turbidity, all sites within this subbasin were rated as good quality. The mean value at each station was less than 20 NTU for 2003-2004.

Nutrient loading, especially of Nitrate-N and total phosphorus (TP) was a severe problem at BC117 (Figures 3.10.4 and Figure 3.10.5). Both Nitrate-N and TP were the highest levels seen in the LCFRP system. These levels were far above the concentrations known to lead to algal bloom formation, bacterial increases and increased biochemical oxygen demand (BOD) in blackwater streams (Mallin et al. 2001, Mallin et al. 2002). BCRR and ANC also periodically experienced elevated nutrient levels as well.

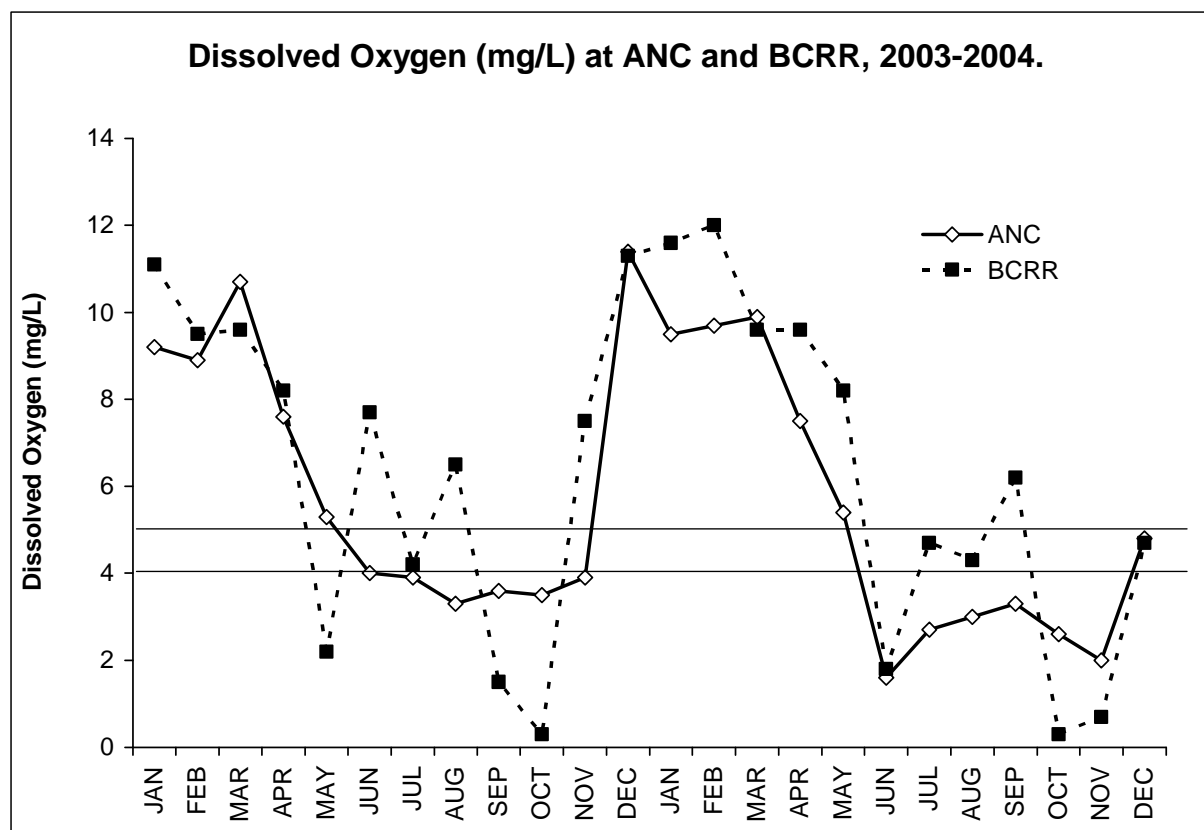


Figure 3.10.1 Dissolved oxygen concentrations (mg/L) for 2003-2004. The lines show the NC State Standard of 5.0 mg/L and 4.0 mg/L (swamp water).

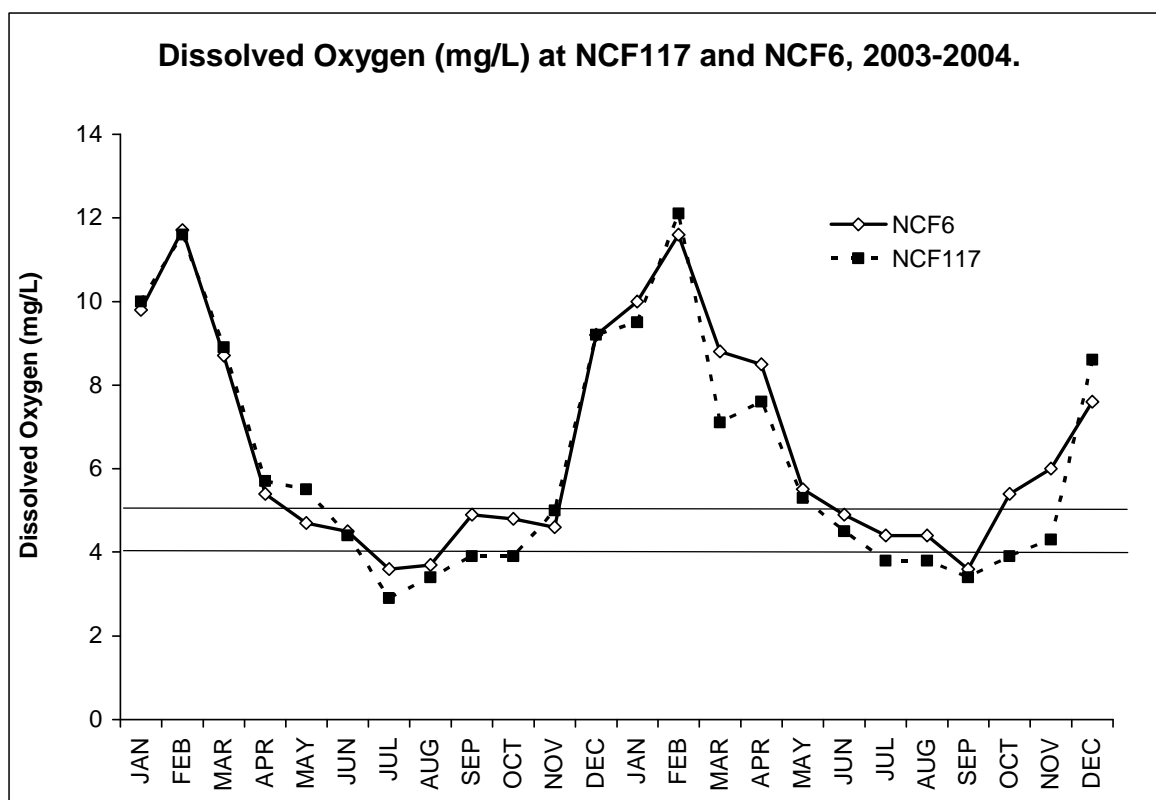


Figure 3.10.2 Dissolved oxygen concentrations (mg/L) at NCF117 and NCF6, 2003-2004. The lines show the NC State Standard of 5.0 mg/L and 4.0 mg/L (swamp water).

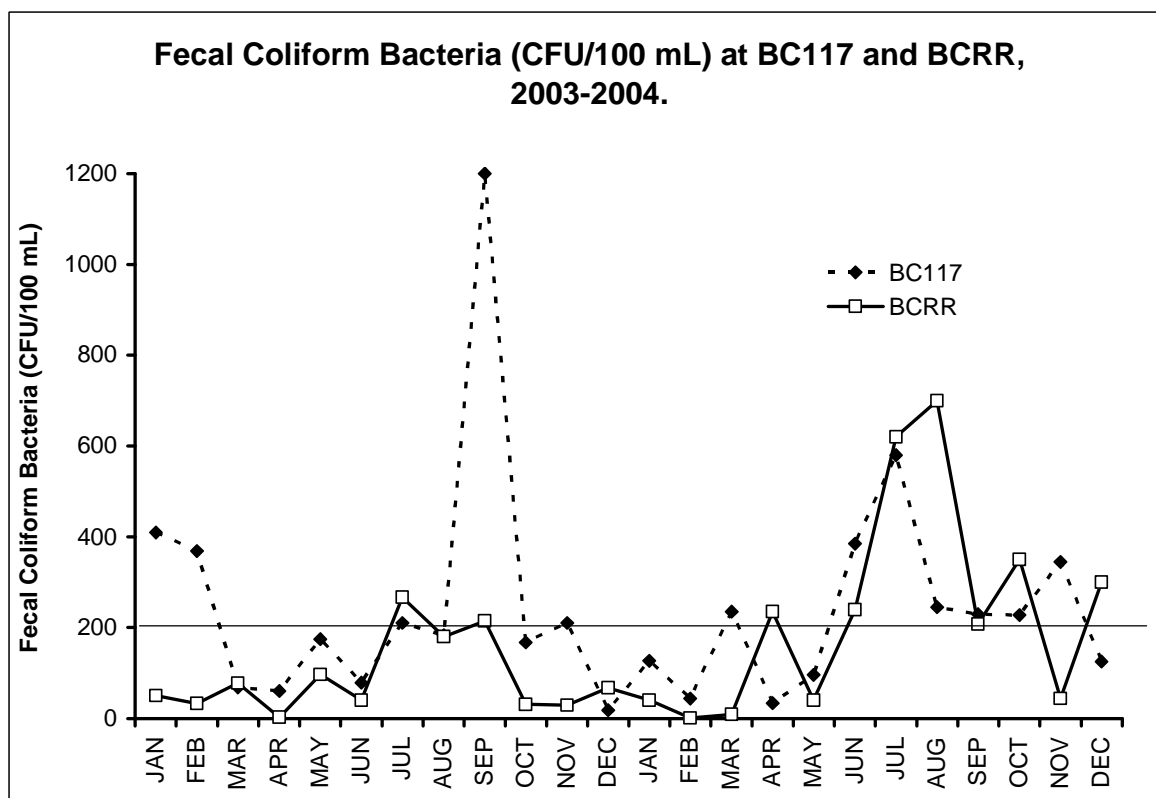


Figure 3.10.2 Fecal coliform bacteria concentrations (CFU/100mL) at BC117 and BCRR, 2003-2004. The line shows the NC State Standard for human contact waters of 200 CFU/100mL.

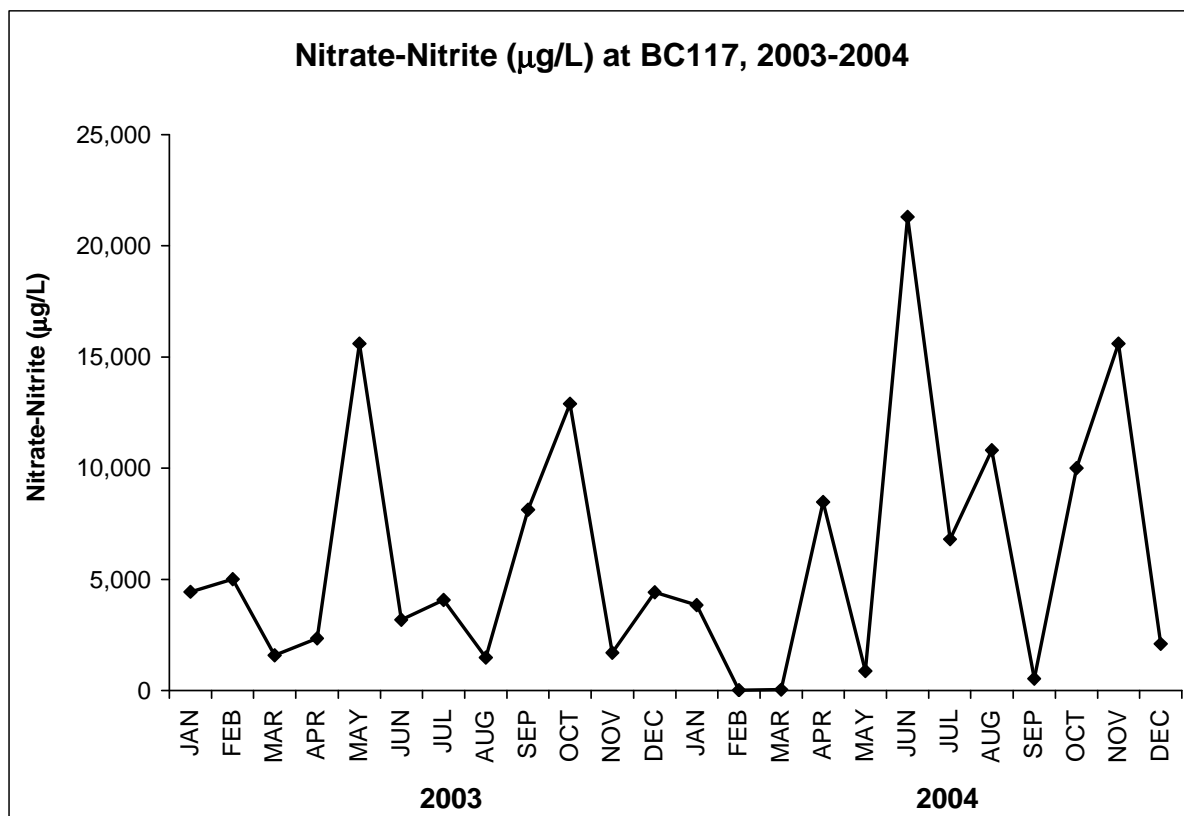


Figure 3.10.4 Nitrate-nitrite concentrations ($\mu\text{g/L}$) for BC117, 2003-2004.

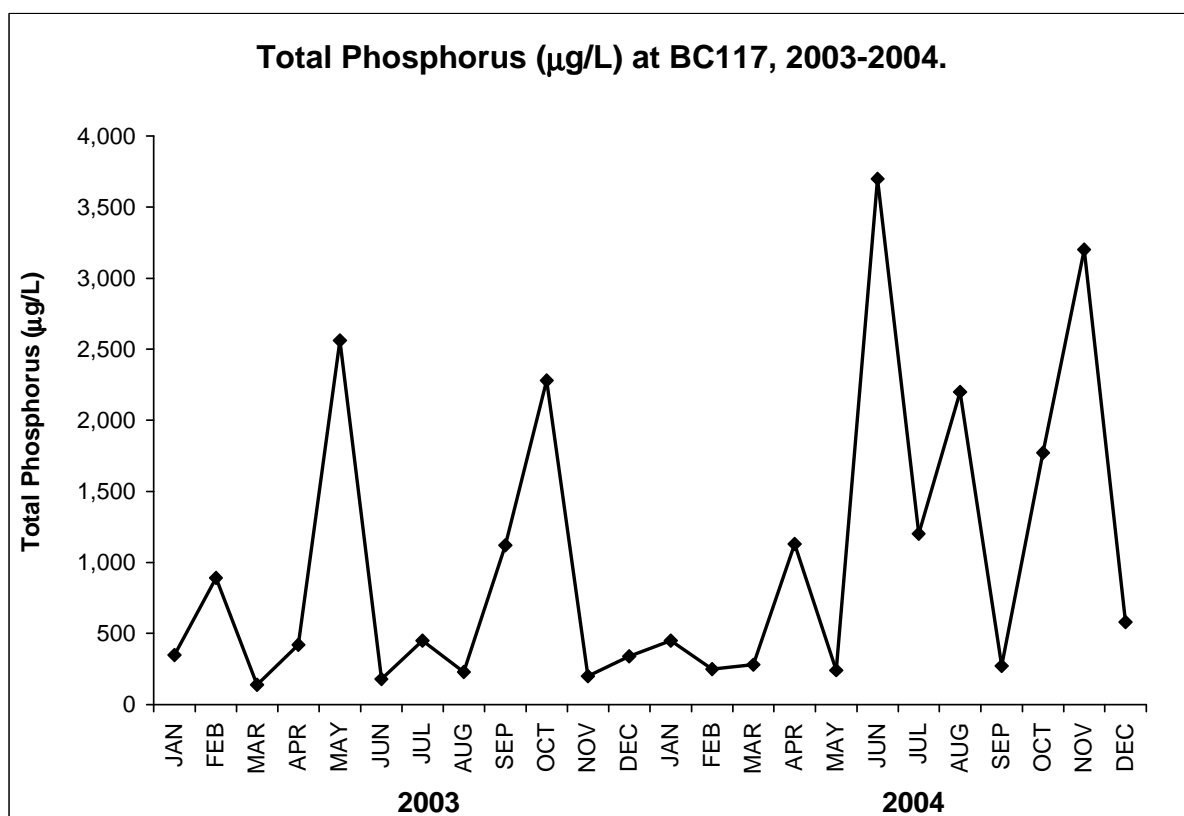


Figure 3.10.5 Total phosphorus concentrations ($\mu\text{g/L}$) at BC117, 2003-2004.

3.11 Summary Table

Table 3.11.1 UNCW-AEL ratings of Lower Cape Fear River Program stations, based on January 2003 – December 2004 monitoring data.

G (good quality) – standard exceeded in < 10% of the measurements

F (fair quality) – standard exceeded in 11-25% of the measurements

P (poor quality) – standard exceeded in > 25% of the measurements

Subbasin	Station	DO	Swamp DO	Chl a	Fecal Coliform Bacteria	Turbidity	Excessive Nutrients
03-06-16	BRN HAM NC11	G P (33%) G	G G G	G G G	F (17%) P (29%) G	G G G	
03-06-17	LVC AC DP IC NAV HB BRR M61 M54 M42 M35 M23 M18 SPD	F (13%) G F (13%) F (21%) P (13%) F (17%) F (17%) F (13%) G G G G G G G		G G G G G G G G G G G G G G G	G G G G G G G G G G G G G G G	G F (13%) G G G F (21%) F (17%) F (13%) F (25%) F (25%) G G G G G	
03-06-18	SR	P (54%)	P (50%)	G	G	G	
03-06-19	LCO GCO 6RC	G P (38%) G		G G G	G G G	G G G	Nit Nit Nit
03-06-20	COL B210 BBT	F (21%) F (25%) F (25%)	G F (13%) F (13%)	G G G	G G not sampled	G G G	
03-06-21	N403	P (58%)	P (50%)	G	G	G	TP & Nit
03-06-22	PB GS SAR LRC ROC	F (25%) P (46%) F (21%) G G	F (21%) P (42%) G G G	G G G G G	F (29%) F (17%) G F (17%) F (13%)	G G G G G	Nit Nit TP TP
03-06-23	ANC BCRR BC117 NCF117 NCF6	P (50%) P (42%) F (17%) P (46%) P (46%)	P (46%) P (25%) G P (33%) F (13%)	G G G G G	F (13%) P (38%) P (46%) G G	G G G G G	TP & Nit

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Chapter 4. A Pilot Study of Metals and Organic Pollutants in Sediments, Clams and Fish Tissue in the Lower Cape Fear River Watershed

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Executive Summary

Researchers at the University of North Carolina Wilmington's Center for Marine Science performed a pilot study in 2003-2004 to assess metals and organic contaminant concentrations at three areas in the Lower Cape Fear River system. This pilot study was funded by the North Carolina Attorney General's Office as part of the Smithfield Agreement. Sites examined were Livingston Creek along the mainstem of the Cape Fear River near Riegelwood, Six Runs Creek in the Black River Basin, and Rockfish Creek in the Northeast Cape Fear River basin. The results of the investigation showed that levels of metals and organic pollutants in the sediments were below limits considered harmful to aquatic life. However, results of fish tissue and clam tissue analyses showed that concentrations of arsenic, cadmium, mercury, selenium, and now-banned PCBs (polychlorinated biphenyls) and the pesticide Dieldrin were above levels considered safe for human consumption by the U.S. EPA and North Carolina Health Director's Office. The reason the levels are elevated in the fish and clams but not the sediments is that these pollutants become more concentrated as they move up the food chain (from water and sediments to algae and insects to higher organisms), a process called biomagnification. These pollutants will also biomagnify in humans. Because this indicates a direct threat to human health, we recommend that a large-scale study be funded to assess levels of these pollutants in fish and clams at stations distributed throughout the lower Cape Fear Watershed.

Introduction

Metals in the environment may come from natural or man-made sources. Metals in the water or sediments can be absorbed or adsorbed by small organisms, such as algae and bacteria, which are then consumed by larger organisms. As these larger organisms are eaten by even larger ones, the metals may build up to high concentrations in their tissues, a process called bioaccumulation. If humans consume fish or shellfish that have high enough tissue concentrations of metals they can experience serious health effects. Thus Federal and State agencies issue warnings if the fish in an area are unsafe to eat due to excessive tissue metals concentrations. Presently in North Carolina there is a fish consumption advisory for the lower Cape Fear River basin due to mercury contamination of fish tissue. The fish consumption advisory is widespread in fresh and in coastal North Carolina waters (<http://www.schs.state.nc.us/epi/fish/contaminants.html>). Freshwater fishes included in the advisory are chain pickerel, largemouth bass and bowfin. In saltwater areas along the North Carolina coast the advisory covers shark, tilefish, swordfish and king mackerel. The known sources of mercury to this area include airborne inputs from distant fossil fuel power plants,

and a former industry located just upstream of Livingston Creek. The basin also is affected by discharges from numerous other point and non-point sources that may contain varying amounts of metals. Therefore, a pilot survey (funded by the Attorney General's office through the Smithfield Foods agreement) was conducted to examine metals concentrations in selected sediments, fish tissue and clam tissue. The U.S. EPA has listed numerous pollutants that can be harmful to humans if regularly consumed in fish and shellfish. Therefore, in addition to metals, concentrations of organic contaminants such as PCBs (polychlorinated biphenyls), PAHs (polycyclic aromatic hydrocarbons), DDT and various other pesticides were assessed.

The State of North Carolina has no official guidelines for sediment concentrations of metals and organic pollutants in reference to protection of invertebrates, fish and wildlife. However, academic researchers (Long et al. 1995) have produced guidelines (Table 4.1) based on extensive field and laboratory testing that are used by the US Environmental Protection Agency in their National Coastal Condition Report II (US EPA 2004).

There are no North Carolina or Federal Standards for fish or clams concerning metals or organic pollutant body burdens that may pose a physiological or ecological risk to the fish. However, the US EPA (2000a,b) has risk guidelines for four metals and several organic pollutants concerning human consumption based on four meals per month. The North Carolina Division of Water Quality has human health screening guidelines for four metals, and the N.C. Health Director has human health guidelines for mercury, selenium and total PCBs for issuing a consumption advisory (Table 4.2; NCDENR 2001).

Table 4.1. Guideline values for sediment metals and organic pollutant concentrations (ppm, or $\mu\text{g/g}$, dry wt.) potentially harmful to aquatic life (Long et al. 1995; U.S. EPA 2004).

ERL (Effects range low) concentrations below ERL are those in which harmful effects on aquatic communities are rarely observed. ERM (Effects range median) concentrations above ERM are those in which harmful effects would frequently occur. Concentrations between ERL and ERM are those in which harmful effects occasionally occur.

Metal	ERL	ERM
Arsenic (As)	8.2	70.0
Cadmium (Cd)	1.2	9.6
Chromium (Cr)	81.0	370.0
Copper (Cu)	34.0	270.0
Lead (Pb)	46.7	218.0
Mercury (Hg)	0.15	0.71
Nickel (Ni)	20.9	51.6
Silver (Ag)	1.0	3.7
Zinc (Zn)	150.0	410.0
Total PCBs	0.0227	0.1800
Total PAHs	4.02	44.80
Total DDT	0.0016	0.0461

Table 4.2. Official human health standards (as ppm, or µg/g) for metals and selected organic pollutants in fish tissue (US EPA 2000b; US EPA 2004; NCDENR 2001)

EPA non-cancer health risk:

Arsenic (inorganic): 0.35-0.70; cancer risk 0.008-0.016

Cadmium: 0.35-0.70

Mercury: 0.12-0.23

Selenium: 5.9-12.0

Total DDT: 0.059-0.12; cancer risk 0.035-0.069

Dieldrin: 0.059-0.12; cancer risk 0.00073-0.0015

Endosulfan: 7.0-14.0

Lindane: 0.35-0.70; cancer risk 0.009-0.018

Total PAHs: 0.0016-0.012 (cancer risk)

Total PCBs: 0.023-0.047; cancer risk 0.0059-0.012

NC DWQ screening levels used to evaluate the need for further intensive site specific monitoring

Arsenic (inorganic): 0.026

Cadmium: 4.0

Mercury: 0.40

Selenium: 20.0

Total PCBs: 0.02

Total DDT: 0.117

Dieldrin: 0.0025

Endosulfan: 24.0

Lindane: 0.0307

NC Health Director human health risk concentrations for issuing a consumption advisory

Mercury: 0.4

Selenium: 5.0

Total PCBs: 0.05

Methods

Sediment collections for metals analysis were done in Six Runs Creek (Black River basin), Rockfish Creek (N.E. Cape Fear River basin), and Livingston Creek (mainstem Cape Fear River). Samples were collected using a petite ponar grab at Livingston Creek (by boat) and at Six Runs Creek. (from a bridge, upstream side). At these two sites, three grab samples were taken, the top layer of sediment (approximately 3cm) was scooped using a stainless steel spoon, put into a stainless steel bowl and mixed, polypropylene (8oz., metals) and polystyrene (4 oz., mercury) jars were filled and put on ice. The samples at Rockfish Creek were collected by scooping the top layer of sediment (approx. 3 cm) into directly into each jar.

Tissues from bottom-feeding fish (bowfin, *Amia calva*) and clams (*Corbicula spp.*) were collected and analyzed for metals. Sites included Six Runs Creek (Black River basin), Rockfish Creek

(Northeast Cape Fear River basin), and Livingston Creek (mainstem Cape Fear River near Riegelwood). The fish were collected from a boat using electroshocking. They were immediately placed on ice until return to the laboratory. Whole fish were wrapped in clean aluminum foil, sealed in ziplock bags, labeled, and frozen. They were then shipped frozen overnight to the Marine Ecotoxicology Branch, Center for Coastal Environmental Health and Biomolecular Research, National Oceanic and Atmospheric Administration, National Ocean Service in Charleston, S.C. for analysis. Bowfin livers and bowfin filets (skin off) were analyzed. Clams were collected by hand, placed unshucked into ziplock bags, and shipped overnight on ice to the NOAA Marine Ecotoxicology laboratory in Charleston for metals and organic pollutant analysis.

Results and Discussion

Results of sediment analyses

At all three sites (Table 4.3) the concentrations of As, Cd, Cr, Cu, Pb, Hg, Ni, Ag and Zn were safely below accepted standards for protection of aquatic life (Table 4.1). Common standards are not available for Al, An, Be, Co, Fe, Li, Mn, Sn and other metals examined. Likewise, all three sites had sediment concentrations of total PCBs, total PAHs, and total DDTs that were below the ERLs (Table 1). Individual pesticides and other organic pollutants were below the laboratory detection limits (not shown).

Table 4.3. Metals and organic pollutant concentrations (as $\mu\text{g/g}$, or ppm) in sediments from three sites in the lower Cape Fear River basin, 2004.

Site	Livingston Creek	Rockfish Creek	Six Runs Creek
Arsenic	<0.909	<0.896	<0.909
Cadmium	<0.0895	<0.0913	<0.0900
Chromium	1.94	5.56	5.91
Copper	<6.10	<6.22	<6.13
Lead	5.38	1.69	4.30
Mercury	0.00196	0.00257	0.00496
Nickel	<1.07	<1.10	2.51
Silver	<0.262	<0.268	<0.264
Zinc	<15.6	<15.9	32.2
Total PCBs	0.0049	0.0064	0.0036
Total PAHs	0.00827	0.01307	0.0344
Total DDTs	0.0	0.00060	0.0

Results of fish and clam tissue analyses

The data showed that freshwater clams and bottom-feeding fishes in the lower Cape Fear River basin contain tissue concentrations (of the four metals having standards-Table 4.2) that are potential human health problems. Arsenic in bowfin livers from Rockfish Creek, Livingston Creek and Six Runs Creek exceeded the recommended concentration range for cancer risk (Table 4.4; Fig. 4.1). Cadmium in bowfin livers and clam tissue from Rockfish Creek, Livingston Creek and Six Runs Creek exceeded the recommended concentration range for non-cancer health risk (Table 4.4; Fig. 4.2). Mercury in all fish and clam tissues examined exceeded the recommended concentration ranges for non-cancer health risk (Fig. 4.3), and selenium in bowfin livers from Rockfish Creek, Livingston Creek and the Six Runs Creek exceeded recommended concentration ranges for non-cancer health risk (Table 4.4; Fig.4.4).

Although there are tissue concentration guidelines for only four metals, the results indicate a metals problem in this basin. These organisms were chosen for analysis because their living habitat or feeding modes are most likely to concentrate potential contaminants. Bowfin are bottom-feeding fish, which are most likely to encounter pollutants associated with the sediments or bottom dwelling prey items, and fish livers concentrate toxins. Clams are filter feeders, and concentrate pollutants associated with suspended particles and benthic particles, including benthic microalgae.

Determining the potential sources of the four metals in question is important to any mitigation strategies. Sources of arsenic include fossil fuel power plant emissions, hazardous waste site leachate, wood preservatives, pesticides and herbicides, and mining/smelting operations (US EPA 2000a). Sources of cadmium include mine drainage, waste disposal operations, paints, batteries, plastics, pesticides and herbicides (US EPA 2000a). As mentioned, mercury can arrive onsite through airborne sources from coal-fired power plants upwind (US EPA 2000a). In the sediments of blackwater swamps and rivers it transforms to the toxic methyl mercury form, a bacterially mediated process. Another potential source is the former Holtrachem plant, which was located just upstream of International Paper in Riegelwood along the Cape Fear River. One major source of selenium is emissions from fossil fuel combustion, and leachate from ash ponds associated with coal-fired power plants (US EPA 2000a). Several coal-fired power plants are located inland along the upper Coastal Plain and in the Piedmont, and one (the Sutton Plant) is located 20 km downstream of Livingston Creek sampling site, near the head of the estuary. Selenium also is abundant in certain soils, but mostly in the southwestern U.S.

Concentrations of PCBs exceeded levels considered safe for human consumption in bowfin filets, bowfin livers, and clam tissue at all three locations (Table 4.4; Fig. 4.5). Concentrations of total DDTs exceeded the safe level in bowfin filets at Six Runs Creek and Rockfish Creek, but only slightly. Concentrations of the pesticide Dieldrin exceeded levels associated with cancer risk in bowfin filets and bowfin livers at all three sites, and in clam tissue at Rockfish Creek (Fig. 4.6). Concentrations of total PAHs were below the analytical detection limit for all samples, and concentrations of pesticides other than DDT and Dieldrin were below the EPA recommended standards in tissue from all three sites.

PCBs were previously used as lubricants, hydraulic fluids, and insulating fluids in electrical transformers, compressors, vacuum pumps and other equipment. They are closely related to

chlorinated hydrocarbon pesticides. PCBs were banned by the EPA in 1979, but are very persistent and bioaccumulate in the food chain (US EPA 2000a). Some studies have indicated that PCBs, through ingestion of contaminated fish, have caused various developmental effects in children including lower IQ, birth weight, and other effects. Various individual PCBs may cause liver problems, cardiovascular toxicity, neurological problems, and cancers (US EPA 2000b). Although banned, PCBs enter the environment through landfills and waste dumps, and are spread through airborne deposition as well as by water. DDT and its metabolites, DDD and DDE are organochlorine compounds that were extensively used in the past as pesticides. They are persistent in the environment and bioaccumulate in the food chain. These compounds cause reproductive and developmental toxicities, chromosomal damage, and considered probable human carcinogens (U.S. EPA 2000b). The use of DDT in the United States was banned in 1972, but it is still sold overseas. Though long banned in the U.S., its persistency in the environment causes it to still be present in water, soil, and food. Dieldrin is an organochlorine pesticide previously used to control termites and soil dwelling insects, and was used on corn, cotton, and citrus crops (U.S. EPA 2000a). The U.S. EPA banned many uses of Dieldrin in 1974, and the remaining uses were terminated by industry in 1987. It is known to cause reproductive and developmental toxicity and cancers in animals, and neurological toxicity in animals and humans. It is persistent in the environment and is also a breakdown product of aldrin, another pesticide no longer in use.

Summary

In summary, metals and organic pollutant concentrations in sediments from Rockfish Creek, Six Runs Creek, and Livingston Creek were below concentrations considered harmful to the health of benthic invertebrates. However, bottom dwelling fish (bowfin) and clams in Rockfish Creek, Livingston Creek and Six Runs Creek showed levels unsafe for human consumption for arsenic, cadmium, mercury and selenium. Unsafe concentrations of PCBs and the pesticide Dieldrin were found in bowfin and clams at all three sites, and unsafe concentrations of DDT were found in bowfin in Six Runs Creek and Rockfish Creek. We recommend that a large-scale survey of bottom fish and clam tissue be initiated for assessing the distribution and magnitude of metals and organic pollutant contamination throughout the lower Cape Fear River basin. This is essential in that if contaminants that cause cancer and other health effects are at dangerous levels in fish and clams, the public and the regulatory agencies need to know where and in what organisms these levels are found. Furthermore, the State should conduct an assessment of potential sources of metals and organic pollutant pollution throughout the lower watershed as a proactive means of protecting human health.

Acknowledgements

We thank the North Carolina Attorney General's Office for funding through the Smithfield Agreement to the Lower Cape Fear River Program. For support for the LCFRP we thank Ms. Marian McPhaul and for field collection help we thank Mr. Mike Williams. For analyses facilitation we thank Drs. Geoff Scott, Mike Fulton, and Ed Wirth at the Center for Coastal Environmental Health and Biomolecular Research, National Oceanic and Atmospheric Administration, National Ocean Service in Charleston, S.C.

Table 4.4. Metals concentrations (µg/g, or ppm) in bowfin filets and livers and clam tissue from Livingston Creek, Six Runs Creek, and Rockfish Creek. Bowfin filets and liver, n = 2 for all three sites. For clams, at Livingston Creek n = 2, for Six Runs Creek and Rockfish Creek n = 1. Values are mean ± standard deviation. *Arsenic concentrations are estimated as inorganic As, computed as 2% of total As.

Metal	Tissue	Livingston Creek	Six Runs Creek	Rockfish Creek
Arsenic*	bowfin filet	0.039±0.003	0.027±0.011	0.024±0.002
Arsenic*	bowfin liver	0.010±0.001	0.013±0.001	0.011±0.003
Arsenic*	clam tissue	0.068±0.001	0.056	0.044
Cadmium	bowfin filet	0.0154±0.000	0.0109±0.0018	0.013±0.0008
Cadmium	bowfin liver	1.68±0.17	0.742±0.620	0.925±0.346
Cadmium	clam tissue	2.01±0.25	2.54	2.13
Mercury	bowfin filet	7.23±1.79	3.15±2.67	5.76±3.78
Mercury	bowfin liver	4.30±0.64	3.96±4.36	4.95±4.92
Mercury	clam tissue	0.46±0.03	0.32	0.94
Selenium	bowfin filet	1.90±0.20	1.60±0.52	1.93±0.23
Selenium	bowfin liver	77.95±9.26	105.60±67.03	62.75±62.58
Selenium	clam tissue	3.77±0.01	3.91	4.02
Total PCBs	bowfin filet	0.0885±0.0361	0.1430±0.0651	0.0635±0.0134
Total PCBs	bowfin liver	0.1895±0.0445	0.0325±0.0219	0.1400±0.0057
Total PCBs	clam tissue	0.1485±0.0431	0.1490	0.2220
Total PAHs	bowfin filet	BDL	BDL	BDL
Total PAHs	bowfin liver	BDL	BDL	BDL
Total PAHs	clam tissue	BDL	BDL	BDL
Total DDTs	bowfin filet	0.024±0.006	0.048±0.019	0.036±0.001
Total DDTs	bowfin liver	0.015±0.022	0.0	0.021±0.071
Total DDTs	clam tissue	0.031±0.005	0.012	0.027
Dieldrin	bowfin filet	0.0043±0.0004	0.0037±0.0052	0.0320±0.0056
Dieldrin	bowfin liver	0.0091±0.0069	0.0096±0.0003	0.1650±0.0665
Dieldrin	clam tissue	BDL	BDL	0.0019

Bolded concentrations exceed either the NC Health Director standards or the US EPA standards. Bolded As, total DDTs, and Dieldrin clam tissue values are for cancer risk; the other metals are for non-cancer health risk.

BDL = below analytical detection limit.

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Figure 4.1. Inorganic arsenic concentrations in bowfin and clam tissue in the Lower Cape Fear River watershed

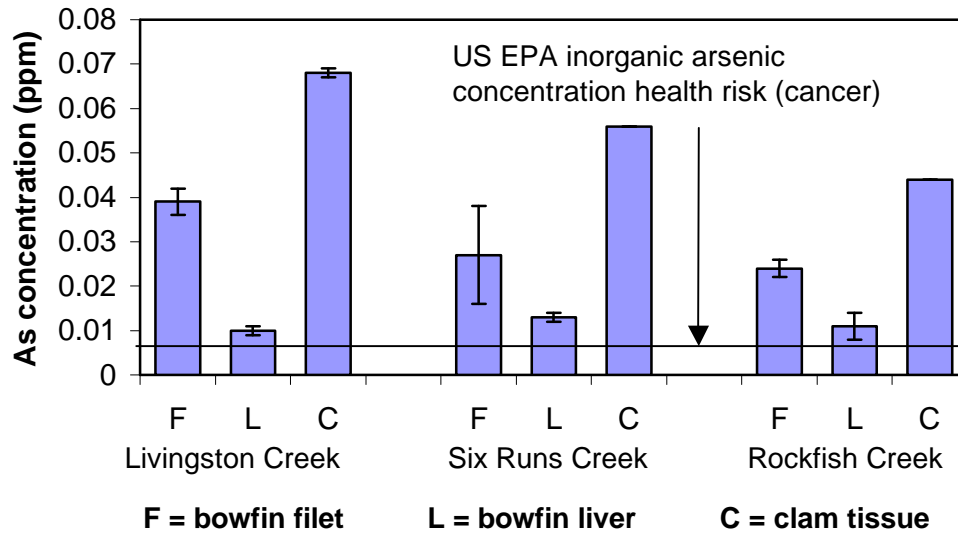


Figure 4.2. Cadmium concentrations in bowfin and clam tissue in the Lower Cape Fear River watershed

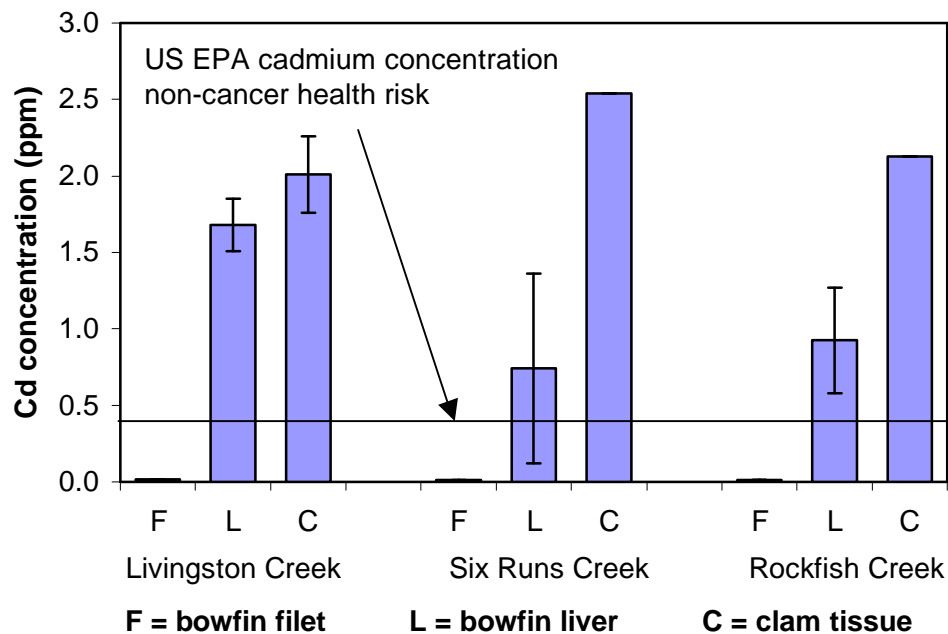


Figure 4.3. Mercury concentrations in bowfin and clam tissue in the Lower Cape Fear River watershed

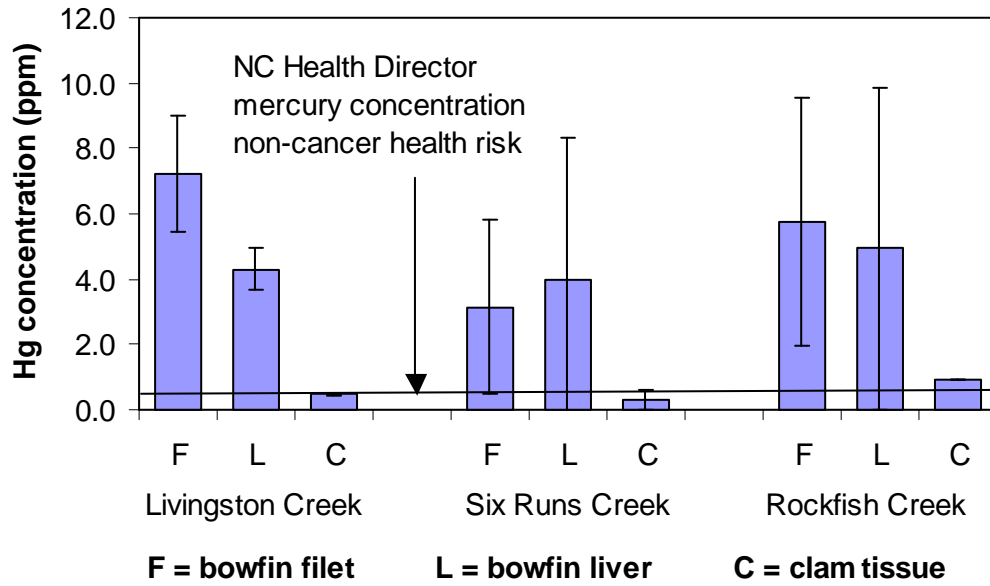


Figure 4.4. Selenium concentrations in bowfin and clam tissue in the Lower Cape Fear River watershed

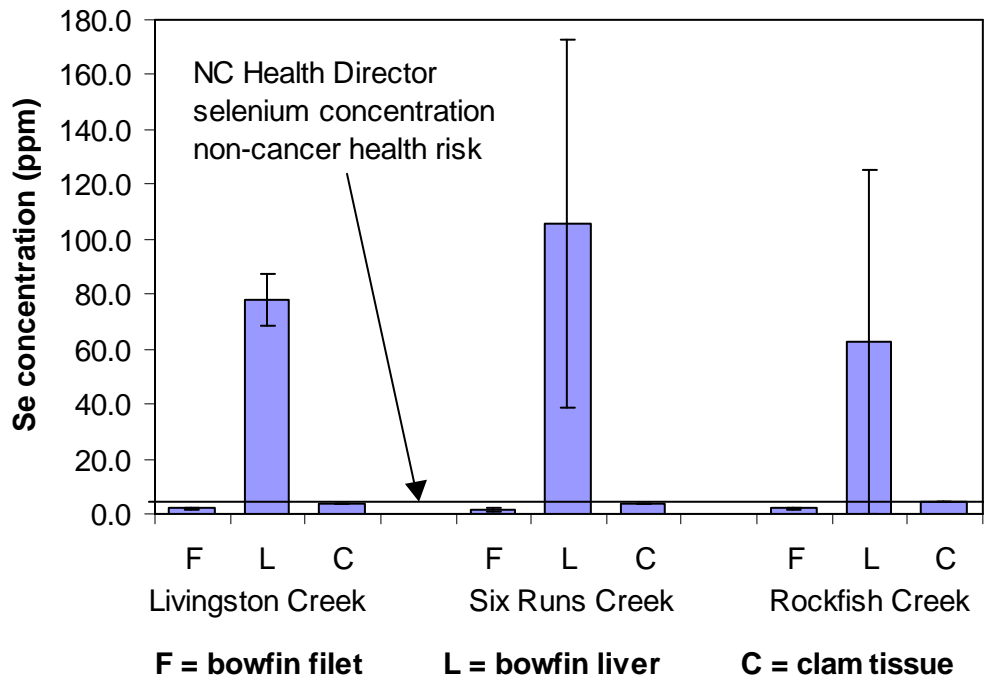


Figure 4.5. Total PCBs concentrations in bowfin and clam tissue in the Lower Cape Fear River watershed

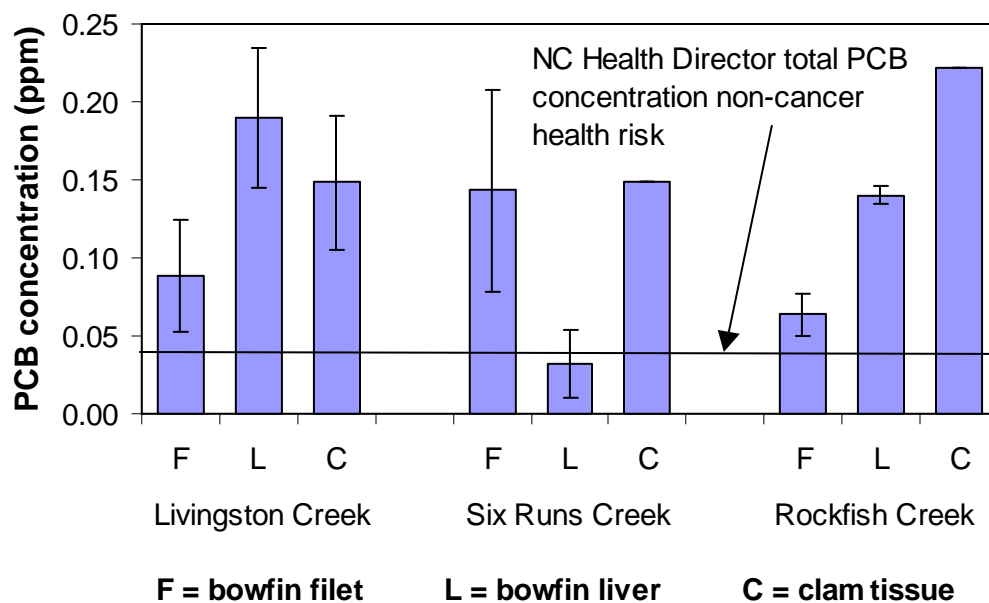
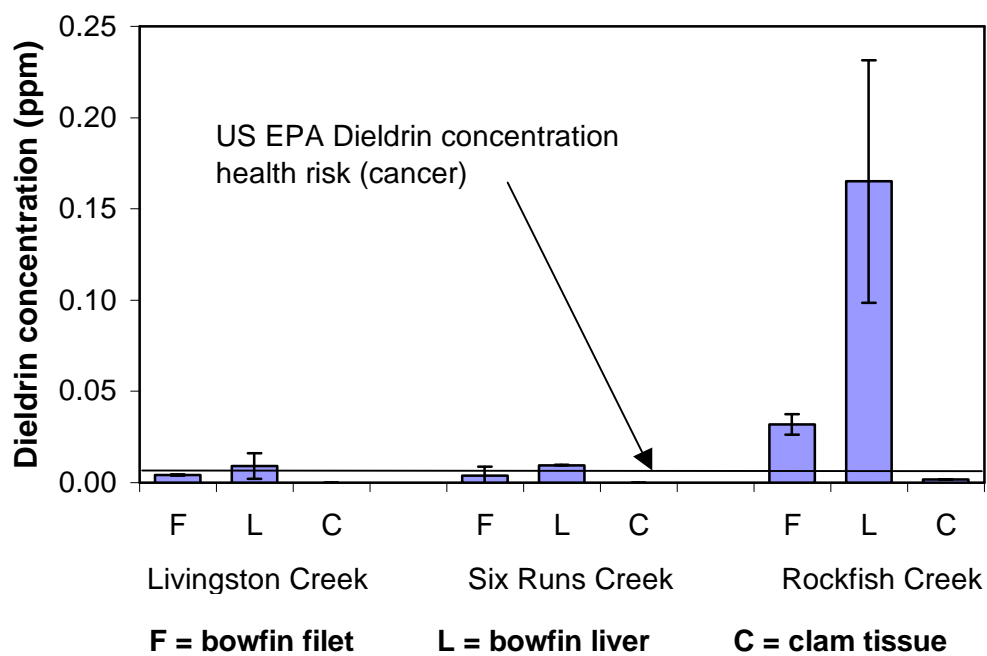


Figure 4.6. Dieldrin concentrations in bowfin and clam tissue in the Lower Cape Fear River watershed



5.0 Oyster Studies in the Lower Cape Fear River Estuary 2003-2004

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5.1 Introduction

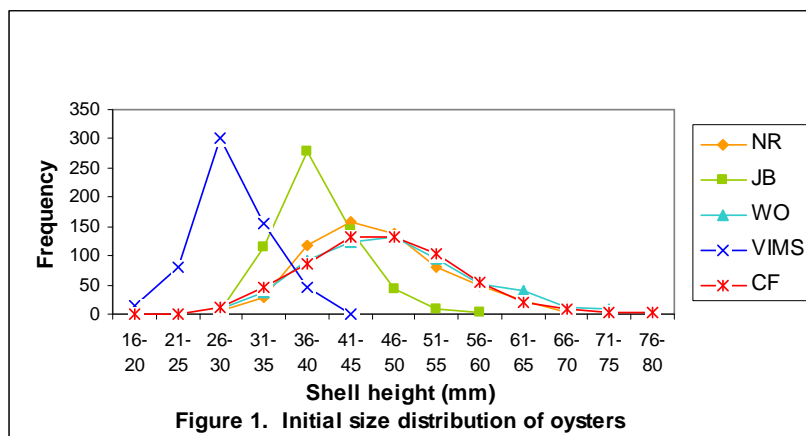
The UNCW Benthic Ecology Laboratory has been an active participant in the Lower Cape Fear River Program since 1995. In that time we have focused on a number of issues related to benthic community structure, the role critical habitats play in the proper function of a healthy ecosystem, and the maintenance of fishery species populations. In recent years concern for the declining population of oysters (*Crassostrea virginica*) has become a paramount issue for fisheries managers in North Carolina and along much of the east coast of the United States. The Lower Cape Fear River Program has supported our proposals to North Carolina Sea Grant and to the North Carolina Fisheries Resource Grant Program to investigate the apparent lack of healthy oyster populations in the Cape Fear River estuary and the potential for stock differentiation among select estuarine systems in the southern and central fishery regions of North Carolina. For this annual report we present data from two projects that have been of interest to the participants of the lower Cape Fear River Program and to state resource managers. The first is an evaluation of larval settlement in the lower Cape Fear River estuary. The second study is a comparison of potential stock differentiation among oysters from several North Carolina estuarine systems of North Carolina, including the Cape Fear River.

5.2: Evaluation of Potential Stock Differentiation

The evaluation of North Carolina oyster stocks on a regional basis, with a focus on developing an oyster stock with consistent performance in North Carolina waters, has great potential for both the oyster growers and restoration efforts within the state. Although there have been efforts to evaluate stock performance for oysters originating from different states and from state and commercial run hatcheries, these evaluations have generally compared only short-term responses of one or two stocks and fail to consider local difference in physical conditions, leaving managers and growers to make anecdotal comparisons and best guess decisions regarding the potential value of particular oyster stocks. Information on potential source effects is critical in the selection of oyster stocks for grow-out. In the case of commercial growers that have to deal with a restricted market, limited resources, and uncertain budgets, "experimenting" with new stocks is risky and a failed year may have disastrous consequences for their livelihood. The issue of oyster performance is not a simple one. High variability in oyster yields between years, and among regions within the state highlights the need for studies that compare the performance of oysters from a variety of local areas within the state. **Our study evaluated the potential for stock differentiation among oysters from distinct estuaries by comparing growth and survivorship among oysters collected from four locations within southeastern North Carolina as well as from a**

hatchery line that is typically available for commercial production. It is important to note that a concurrent companion study evaluated these same stocks for genetic differences based on two genetic markers. Data on the genetic evaluation are not presented here but are available from North Carolina Sea Grant by requesting the final report for FRG 00-AM-07.

This study used reciprocal transplants and a common garden approach to evaluate the performance of five oyster stocks. Recently set oysters were collected from the Cape Fear River estuary (CF), New River Estuary (NR), and White Oak River Estuary (WO). To the extent possible, all oysters from the ambient stocks were from the most recent set. As a control for stock origin, a hatchery stock from the Virginia Institute of Marine Science hatchery (VIMS) was also used. The hatchery stock is readily available for commercial growers and presumably has been selected for faster growth rates. A fourth stock used in this study originated in Stump Sound, North Carolina. Brood stock from Stump Sound (JB) were spawned in a hatchery and shipped as eyed larvae to J&B AquaFood (managed by Jim Swartzenberg) located at Stump Sound. These larvae were then set on microcultch in a flow-through system using ambient water. Because the goal of this project was to evaluate growth, we tried to limit the initial size distribution of the oysters used for the study, with the majority of individuals used being less than 50mm in shell height. Both of the hatchery-spawned stocks demonstrated slightly lower initial sizes compared to oysters collected from the ambient stock (Figure 1). (Size distributions in Figure 1 are based on shell height (distance from umbo to outer edge of shell) measurements only.



Within two weeks of collection from the field, oysters from each stock were measured for shell height and shell width (defined as the longest axis perpendicular to shell height) and numbered. The numbering allowed us to collect data on the individual growth of each oyster from each stock. Following the initial measurement of the oysters, photographs of each set of oysters were also taken to later reference possible shell breakage and condition. Oysters from each stock were divided into sets of 50 and placed in numbered cages. One of the key aspects of this study was to evaluate how

oysters from each stock performed in relation to the other stocks within each of the estuarine systems that the oysters had originally settled within. To do this three randomly selected cages of each of the five stocks (Cape Fear=CF, New River=NR, White Oak=WO, Stump Sound=JB, and hatchery=VIMS) were placed in each of the four areas (Cape Fear River, New River, White Oak, and Stump Sound). Oysters were placed as close as possible to areas where they had been collected. Because this project was proposed to last one year, small research sanctuaries were established in each area where oysters were planted to help prevent tampering with the experiment during the crucial time period. Cages containing oysters were placed on a rack and cage system (constructed of 4 inch PVC and 1/2 inch rebar) that helped keep the oysters 10-15 cm (4-6 inches) above the bottom, prevented possible sedimentation that would have interfered with the survival and growth of the oysters, and prevented movement of the cages even during storm events. Every 6-8 weeks all the oysters at each location were retrieved from the field and measured for shell height and width. Overall mortality was also recorded at that time.

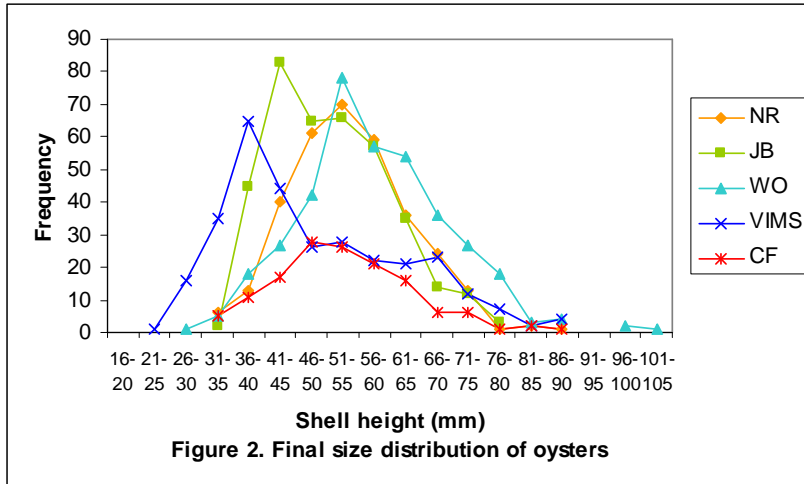
An Analysis of Variance was used to statistically evaluate growth among oyster stocks at each site and among sites for each of the oyster stocks. All analyses were conducted on mean growth per individual, rather than percent growth or on size distributions. Mean growth per individual is a better metric for evaluation of performance and avoids potential bias associated with differential mortality. We were unable to perform any analysis of single oyster stocks among sites due to variable growth periods and high mortality at some sites.

There were several deviations from the original experimental design that did impact the study in some way. Each of these involved oyster mortalities or lost cages, but in all cases these events were beyond the control of the investigators. With regard to the data from the Cape Fear River, these data only reflect growth from March, 2001 to July, 2001. The oysters in this system experienced a major over-spat event in late August-early September, with as many as 30 spat settling on individual oysters causing high mortality. This unusual spat settlement event likely affected both survival and growth of experimental oysters, preventing reliable measurement of the experimental oysters, so comparisons among stocks were made from the last pre-settlement data for the Cape Fear site only. Additional considerations included:

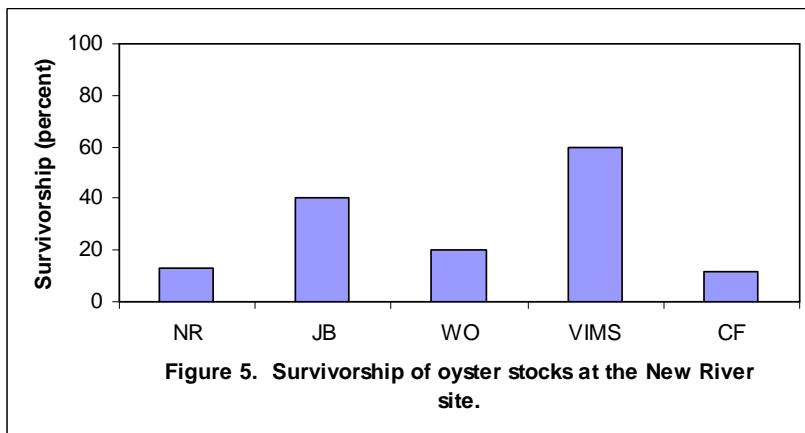
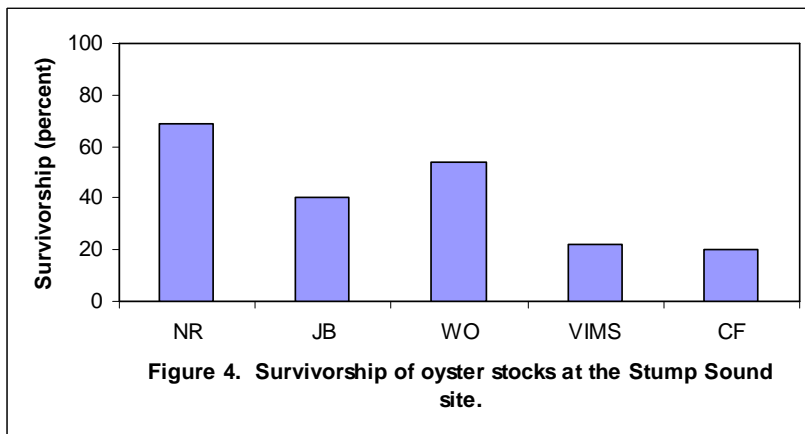
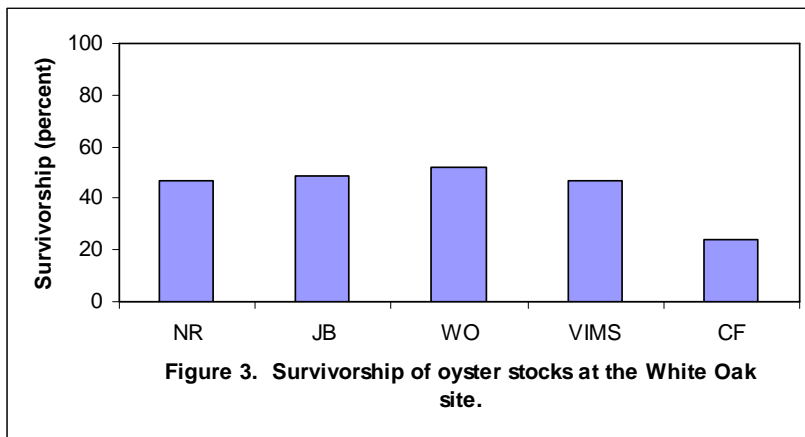
- Although each set of experimental oysters was placed within a research sanctuary we did see evidence of vandalism at the New River Site, where we recovered two numbered cages and numbered oyster shells by the remains of a campfire.
- A single cage was lost at the White Oak site, due to a storm event.
- The drought of 2001-2003 caused significant growing problems at J&B AquaFood among cultured oysters to including *Polydora* sp. and tunicates and significant fouling in cages and chubs, and a high rate of mortality among other oyster crops at this location.

Results

- The size distribution of oysters at the end of the experiment showed relatively consistent patterns among sites (Figure 2), although both the JB and VIMS stocks did show peak numbers at slightly smaller sizes than other stocks. This may reflect slightly smaller initial sizes for these stocks.

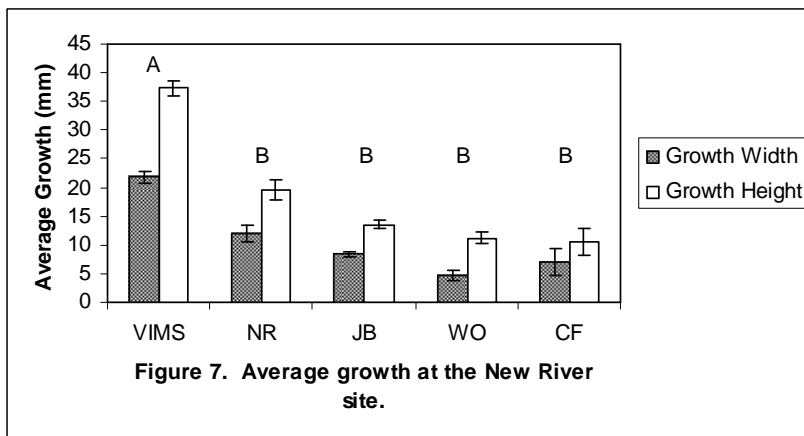
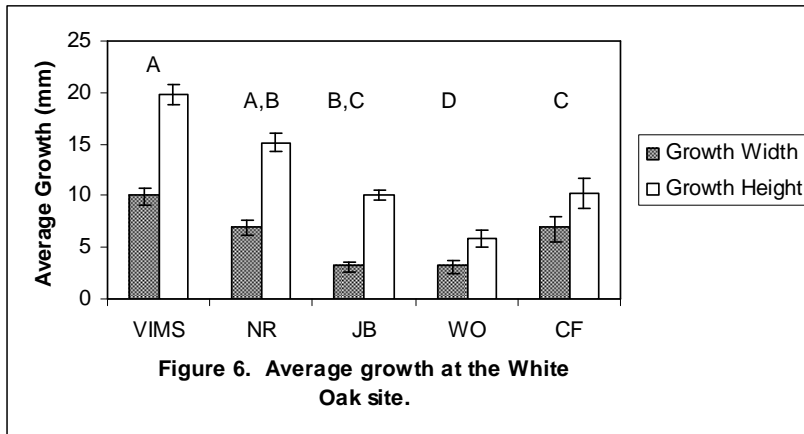


- Because of mass mortality at the Cape Fear site, survivorship data is not available from that area. However, in the four months the Cape Fear site had oysters deployed, there was little mortality among the various stocks. Survivorship data indicated oysters at the White Oak site demonstrated relatively similar survivorship (45-50%) among all stocks, except for low survivorship of the Cape Fear stock (Figure 3). This was not the case with either the New River site or Stump Sound site. Survivorship varied at these sites, with the New River and White Oak stocks showing greater survivorship at the Stump Sound site (Figure 4) and the hatchery stock (VIMS) clearly showing greater survivorship at the New River site (Figure 5). Interestingly, the Stump Sound stock (JB) shows very consistent survivorship among all three sites.

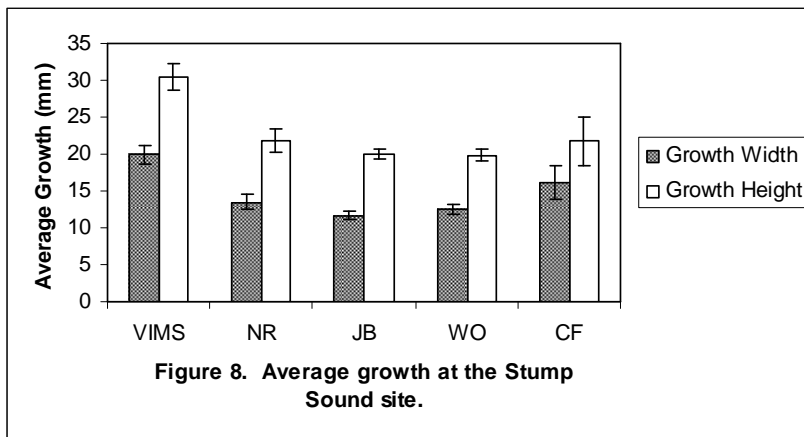


- Comparisons of growth indicated significant differences among stocks at the White Oak site ($F=14.13$, $p<0.0006$) (Figure 6) and New River site ($F=15.44$, $P<$

0.005) (Figure 7). Columns with the same letter designation are not significantly different from one another (based on Student-Newman-Keuls procedure). Surprisingly, the stock from the White Oak performed worse at the White Oak site.



- While the hatchery and New River stocks did perform better at the White Oak site, only the hatchery stock showed any significant increase over other stocks at the New River site. White Oak and Cape Fear stocks did poorest at the New River. There were no differences in growth among the various stocks placed at the Stump Sound site (Figure 8).



- Although comparisons of stocks among sites is not appropriate (experimental duration varied among sites, based on site-specific problems previously mentioned), all five stocks grown at the Stump Sound site did tend to have greater growth than the average growth among stocks at either the White Oak or New River sites. Average increase in shell height at the Stump Sound site was 20mm or more, while average increases in shell height at the other sites was 15 mm or less for all stocks except the hatchery stock control.

Conclusions

- Stock performance, both growth and survivorship, are strongly influenced by local conditions. While the differences were detectable they did not follow a clear site pattern; though growth tended to be less for White Oak and Cape Fear stocks.
- While oysters at some sites may demonstrate good survivorship this may not necessarily translate into high growth. Factors enhancing one aspect of performance may not enhance the other.
- Stock origin did have a lasting impact on performance through the first year. These findings suggest that oysters from different sites demonstrate variability in response to the environment and may experience selection based on local conditions.
- Evaluation of individual growth is an effective method for determining performance and avoids some of the potential bias of analysis on other metrics such as size distribution that is strongly influenced by mortality.

5.3: Evaluation of Spatfall in the Cape Fear River

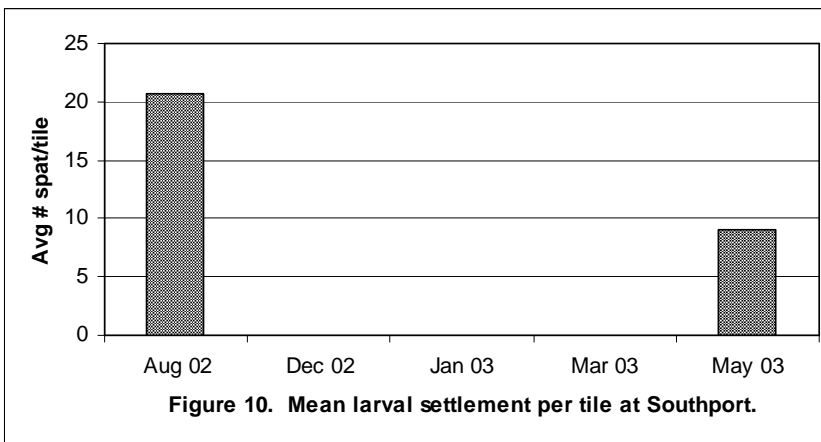
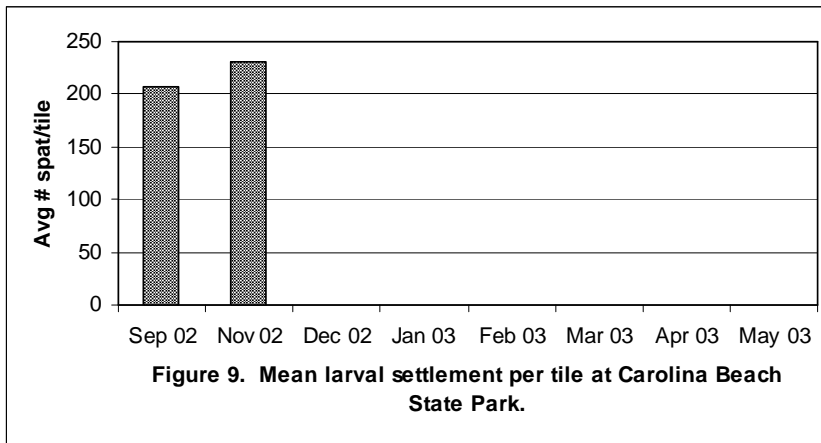
Sparse oyster stocks are present near the mouth of the Cape Fear River as well as within the marshes behind Bald Head Island and on the rock wall at Fort Fisher. There are also records of some subtidal oysters present on rocks in front of Fort Fisher. However, none of these oyster populations are substantial. There are a number of possible reasons for the lack of healthy oyster populations. The first is a lack of larval supply. If oyster larvae cannot reach these locations in sufficient numbers then there is little opportunity to establish sustainable and extensive beds or reefs. The second possible explanation is the lack of suitable settlement habitat for larvae that may reach these areas. This explanation does hold some merit since oysters require hard substrate to settle and metamorphose (preferring the shells of other oysters but they will settle on other hard surfaces as well). The Cape Fear River in general is a dynamic system with little hard substrate, other than in the lower region of the river near Fort Fisher. A third possible explanation is that post-settlement factors such as extreme tide events and/or variation in water quality cause high mortality among recently settled oysters. None of these explanations are mutually exclusive and likely that a combination of these factors may interact among years preventing the establishment of persistent oyster populations.

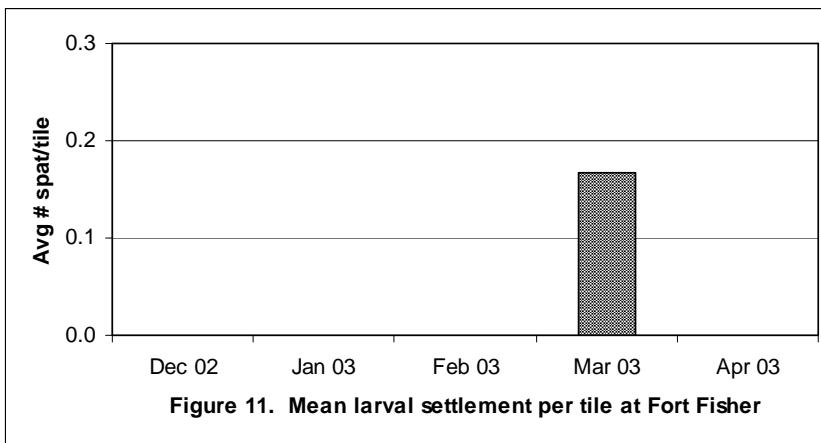
Because larval supply is the most critical point in enhancing oyster populations in the Cape Fear River and the most difficult to overcome, we measured larval settlement among three sites in the Cape Fear River (Carolina Beach State Park, Fort Fisher, and Southport) and control sites in the New River and Stump Sound.

All three sites used for this study were of similar salinity and tidal height. Both of the control sites have a proven record for supporting healthy oyster stocks and productive oyster culture and provide a general idea of the regional timing and intensity of spatfall (larval settlement) for comparison with the Cape Fear. We used nine settlement tiles (8 in. X 8 in.) placed in sets of three, spaced 1m apart at each site. All tiles were in place by April (the time period presumed to be the start of the settlement period for many of the state's estuarine waters). Tiles were collected from each field site every six weeks (and replaced with new ones) and returned to the lab for evaluation. Because newly settled oyster larvae are too small to be reliably seen with the unaided eye, tiles were maintained in a flow through water system with filtered seawater (to prevent additional settlement) for two weeks (after two weeks oyster larvae reach a size of approximately 2mm, large enough to be accurately identified). If larval settlement were the cause of scant oyster populations in the Cape Fear, we would expect to see settlement on Cape Fear tiles lower than that recorded from the control sites

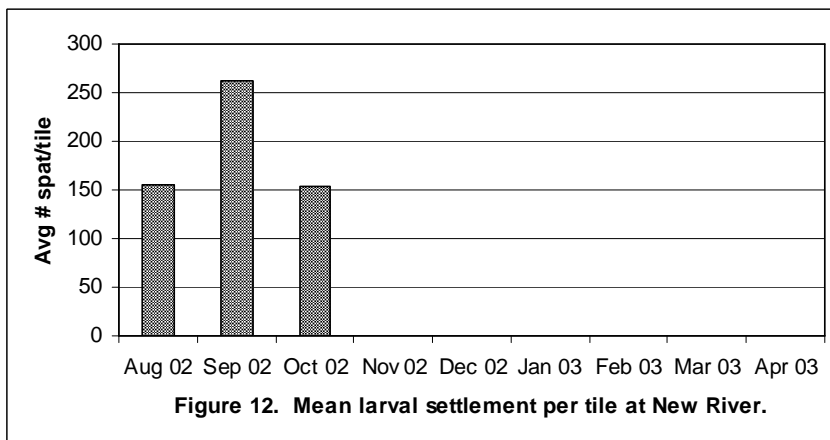
Settlement of oysters in the Cape Fear was highly variable temporally and spatially. Although all tiles were deployed in April, settlement was not detected until August or September for any site. Among the Cape Fear sites, Carolina Beach showed the highest settlement (Table 1, Figure 9), with Southport being intermediate with peak settlement density of 20.75 larvae per tile (Figure 10), and the Fort Fisher site showed the least amount of settlement (Figure 11). It is important to note that all sites in the Cape Fear did have oyster populations (the Carolina Beach site lacks any hard

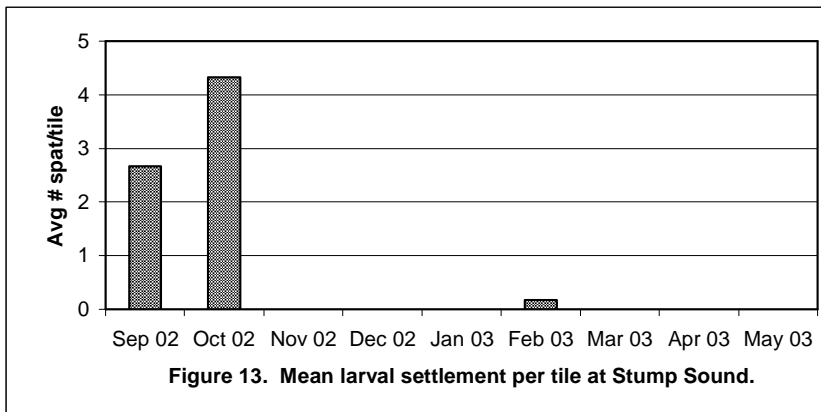
substrate other than docks and pilings where oysters do settle in relatively low densities) but there was not a clear relationship between the density of live oysters at a site and the density of larvae that settled at that site.





The control sites also showed high variation with New River having the highest density of larval set among all sites (Figure 12), while the Stump Sound site had a peak density of 4.3 larvae per tile (Figure 13). Unlike the sites in the Cape Fear, both the New River site and the Stump Sound site have healthy oyster populations with densities of live oysters that exceed 125 oysters per meter square. Both control sites also support active commercial fisheries with leased bottom culture activities adjacent to the research sites.





While two of the Cape Fear sites had peak settlement rates within the ranges of the two control sites, the Cape Fear sites physically contrasted with those control areas by having an apparent lack of naturally occurring settlement substrate. A rock wall and rocky debris at the Fort Fisher site offer the most substantial settlement surfaces of the three sites in the Cape Fear River, and in fact we have recorded densities of oysters at this location that exceed 300 m², even though peak settlement densities were less than 1 per tile. The oyster population at the Fort Fisher site was characterized by dense settlement, predominantly immature individuals (shell height <50mm), and low vertical relief of the oyster aggregates or clusters. Low vertical relief and small size of the oysters at this location may be indicators of poor health of the oysters, either from water quality or possibly from overcrowding. With a limited amount of hard substrate it is likely that the oysters suffer from “over spat” events. This occurs when too many larvae settle in a confined space and begin to compete with one another. We also observed that oysters at this location are easily broken and dislodged. Weak shell strength may be another possible indicator of overcrowding and the poor fitness of the oysters that settle in this region of the river. This is in contrast to the oysters that settle in the other two sites in the Cape Fear where we found oysters in low density, growing solitarily, but otherwise seeming to be normal with regard to shell strength

The combination of periodic but highly variable recruitment at two of the Cape Fear sites but low recruitment at the only site with substantial substrate present leads us to conclude that the lack of substantial oyster populations in the Cape Fear Estuary is due in part to the lack of sufficient settlement substrate to support the larvae that settle in this estuary. The fact that thriving oyster populations are observed in other river systems with comparable larval settlement and settlement substrate throughout the littoral and subtidal zones suggests that settlement substrate does play a key role in the establishment of oyster populations at these sites. This study was a short-term evaluation of oyster settlement for one year and was not designed to be an exhaustive study of the possible mitigating factors that influence oyster populations in the lower Cape Fear estuary. The Cape Fear River is a dynamic system with high flushing rate and variable water quality conditions that may play a role the long-term establishment of oysters.

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Table 1. Settlement tiles were deployed from June 2002 to May 2003. However the number of sampling periods did vary due to weather events and site disturbance (note Fort Fisher site was only sampled from Nov02- Apr03). Settlement months represent the actual number of sampling periods where oyster spat were present. Mean set represents the average number of larvae that settled adjusted for months deployed. Peak set is the peak average settlement actually measured.

Site	Settlement months	Mean Set	Peak Set
Carolina Beach State Park	2	39.84	231.67
Southport	2	2.71	20.75
Fort Fisher	1	0.03	0.17
New River	4	57.02	261.91
Stump Sound	2	7.02	4.33

Conclusions

- Larval settlement in the Cape Fear River is highly variable both temporally and spatially.
- Oyster populations in the Cape Fear River seem to be limited in part by available settlement substrate.
- Oysters at the site with the highest density of live oysters show signs of overcrowding and poor fitness.

Summary

It is important to recognize that oysters are important for several reasons in the estuarine environment. While traditional efforts to manage oyster populations have focused solely on the value of oysters as a fishery our effort in the last 10 years have been devoted to raising public awareness of the ecosystem services that oysters provide, including filtration of pollutants, erosion control, habitat enhancement, support of other fisheries, and enhanced nutrient cycling. Particularly in the last five years a number of conservation and community groups have initiated restoration for the purpose of enhancing these other functions of oysters. As these types of efforts gain recognition it is critical that we initiate the types of studies described here in order to provide information and recommendations that will increase the likelihood of success for these efforts. It is also important to point out that these efforts can and do help oyster production as well.

The evaluation of North Carolina oyster stocks on a regional basis, with a focus on developing an oyster stock with consistent performance (survivorship and growth) in North Carolina waters, has great potential for both the oyster growers and restoration efforts within the state. High variability in oyster yields between years, and among regions within the state highlights the need for studies that compare the performance of

oysters from a variety of local areas within the state. We performed a study that evaluated the potential for stock differentiation among oysters from distinct estuaries by comparing growth and survivorship among oysters collected from four locations within southeastern North Carolina as well as from a hatchery line that is typically available for commercial production. The results showed that stock performance, both growth and survivorship, are strongly influenced by local conditions. While the differences were detectable they did not follow a clear site pattern, though growth tended to be less for White Oak and Cape Fear stocks, and survivorship less for Cape Fear stocks. It is important to realize that while oysters at some sites may demonstrate good survivorship this may not necessarily translate into high growth. Factors enhancing one aspect of performance may not enhance the other.

Because larval supply is the most critical point in enhancing oyster populations in the Cape Fear River and the most difficult to overcome, we measured larval settlement among three sites in the Cape Fear River (Carolina Beach State Park, Fort Fisher, and Southport) and control sites in the New River and Stump Sound. Our results showed that larval settlement in the Cape Fear River is highly variable both temporally and spatially. Oyster populations in the Cape Fear River seem to be limited in part by available settlement substrate. Oysters at the site with the highest density of live oysters showed signs of overcrowding and poor fitness. Thus, substantially increasing the amount of available substrate for larval oyster settlement should prove to be a useful tool for increasing viable oyster populations in the lower Cape Fear River Estuary. Enhancement of oyster populations in the Cape Fear Estuary would have potentially beneficial impacts to water quality, to the future of the oyster fishery and to finfish populations in this region.